APPLE INSECTS in MAINE

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BULLETIN 540

APPLE INSECTS IN MAINE

FRANK H. LATHROP[1]

INSECT CONTROL IS A COMPLEX PROBLEM

Present market conditions demand high standards of excellence for apples, and even light to moderate insect injury may reduce the value of the crop to a considerable degree. Maine growers are fortunate because many of the pests that are exceedingly difficult to control in apple growing sections farther south and west, can be controlled satisfactorily in Maine by routine spray practices. Nevertheless, there are many different kinds of insects that attack apples in Maine, and the total injury to the trees and fruit is often considerable. The Maine apple grower, therefore, is faced with the problem of knowing which pests require attention in his orchard, what treatment is advisable, and when the treatment can be applied most effectively.

All Pest Control Problems Are Interrelated

It has become increasingly evident that the control of the various orchard pests presents interrelated problems. For example, some of the fungicides, applied for scab control, destroy many natural enemies of insects and often permit the rapid build-up of European red mite and oystershell scale. Though he constantly is forced to combat individual pests as they become destructive, the grower should realize that the treatment applied for the control of one pest, sometimes may be followed by increased populations of other destructive insects.

Most of the new insecticides have powerful contact action, and are likely to destroy many of the beneficial insects that help to keep the injurious pests under control. A grower should not hesitate to use the new insecticides, such as DDT, when necessary, but the use of these powerful contact sprays should be discontinued as soon as the pest for which they were applied has been subdued.

The Pest Control Situation Constantly Changes

The destructive capacity of the various insect pests varies greatly in any orchard from year to year. When weather conditions and other factors are favorable for a certain pest, it may increase rapidly and become very destructive. At the same time, some other pest may become

[1] Entomologist, Maine Agricultural Experiment Station.

less destructive. Therefore it is important for the apple grower to vary his spray program from year to year to combat most effectively the particular pests that threaten to cause injury and loss.

This bulletin briefly summarizes the results of observations and experiments on some of the destructive insect pests in Maine apple orchards. There are many insect pests that are not included in this publication. Continued research is needed to help Maine apple growers meet their pest control problems effectively and economically.

There are, of course, a number of species of insects more or less troublesome in Maine apple orchards that are not discussed in this bulletin. Some destructive pests, such as the leaf rollers for example, have not been included, because the information available is not sufficient for a reasonably complete discussion. A few other species, such as the apple leaf-curling midge and the lesser apple worm, are not sufficiently destructive to warrant including them in the bulletin.

APPLE FRUIT FLY[2]

The apple fruit fly is a destructive pest in all of the apple-growing sections of Maine. On neglected trees, practically every apple may be ruined, and in a community where infestation has become excessive, the pest is exceedingly difficult to control. By careful and persistent application of control practices, commercial apple growers in Maine generally keep the loss from fruit fly well below one per cent of the apples. Fruit fly, however, remains a constant threat that demands the continued attention of the successful apple grower.

Injury. Fruit fly injury develops as dark-colored trails, tunnels, and cavities through the flesh of the ripening fruit (fig. 1). In early apples, the injury develops rapidly, and the fruit usually breaks down quickly. In later varieties, the injury may remain as indistinct, sometimes barely visible trails through the flesh of the fruit until well into the winter. In an advanced stage the tunnels frequently show through the skin of the apples as discolored trails or "railroads." In common storage, the injury develops rapidly, but in cold storage the development of the injury is halted.

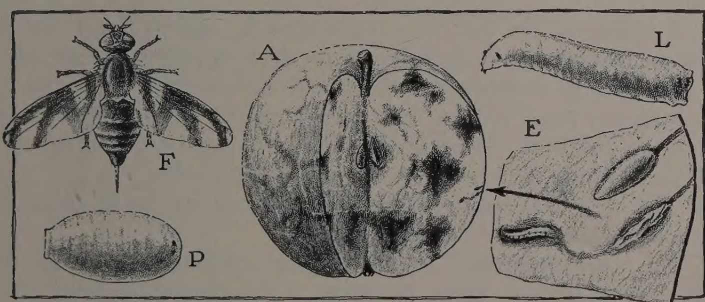


FIG. 1. Life Stages of the Apple Fruit Fly. A.–Severe fruit fly injury. F.–Adult female fly. E.–Shows a newly deposited egg under the skin of an apple, and next to it is a hatched egg with the young larva beginning to tunnel into the apple. The arrow points to the eggs as they appear in the apple. L.–Full grown larva ready to leave the apple. P.–Puparium within which the resting stage of the insect spends the winter.

The exceedingly small punctures, or stings, through which the flies lay their eggs under the skin of the apples, are difficult to see. Juice sometimes oozes out through the egg punctures, giving a sticky feel to the surface of the infested apples. By careful observation, such infested

[2] *Rhagoletis pomonella* (Walsh).

apples often can be distinguished from healthy fruit, by a peculiar, sickly, yellowish tinge on the red areas of the infested apples.

Kinds of Fruits Attacked. Early apples, and especially sweet apples are most likely to be severely infested. Varieties such as Wealthy and McIntosh also are susceptible to severe infestation. Late apples, such as Baldwin and Ben Davis, are somewhat less likely to be severely injured. All varieties may be severely injured, however, when exposed to heavy infestation of flies. Porter (1928) compiled a long list of apple varieties, showing the relative susceptibility of each to fruit-fly infestation.

Besides apples, the apple fruit fly also attacks some other orchard fruits—plums, pears, and possibly cherries—to a limited degree. Several kinds of wild fruits, especially hawthorn (*Crataegus* spp.) and sugar-plum, or shadbush (*Amelanchier* spp.), are freely attacked, and may serve as sources of fruit-fly infestation.

The apple fruit fly and the blueberry fruit fly, technically, are the same species. They are exactly alike, except the apple pest is larger than the blueberry pest, in each of the life stages. The apple fruit fly is not a pest of blueberries, however, and the blueberry fruit fly is not a pest of apples.

Life Stages. The *adult* is a two-winged fly, slightly larger than the common housefly. It is dark brown to black in color, and the wings are marked with a characteristic pattern of dark-colored bands (fig. 1). The male has three, narrow, light-colored stripes across the abdomen; the female has four. The long, needle-like ovipositor of the female is used for inserting the eggs under the skin of the apples.

The *egg* is very small, about 1/50 inch long, narrow in shape, and of a milky-white color.

The *larva,* sometimes called "maggot" or "railroad worm," that hatches from the egg within the apple, is the destructive stage in the development of the fruit-fly pest. The larva is milky white in color and very difficult to see in the flesh of the apple. It is slender, broadly rounded at one end, and bluntly pointed at the other. At the pointed end, there is a pair of dark-colored hook-like teeth, with which the larva tears away the flesh of the fruit, as it feeds and tunnels through the apple. When full grown, the larva attains a length of about 4/10 of an inch.

The *pupa,* or resting stage, is formed within a tough, protective case, the *puparium,* which consists of the last skin shed by the larva. The puparium is about the color and shape of an over-sized grain of wheat. At the proper time the adult fly, male or female, transforms from the pupa, and emerges.

SEASONAL CYCLES

The first careful and comprehensive investigation of the apple fruit fly was made in Maine during the years 1888 and 1889 by Professor F. L. Harvey, Botanist and Entomologist of the Maine Agricultural Experiment Station. Professor Harvey (1890) correctly observed and reported the essential features of the seasonal cycle of the insect. Since that time, many detailed studies have been made by various workers.

Because of the important relation to the control of the pest, the seasonal cycles and habits are summarized here in considerable detail (see fig. 2).

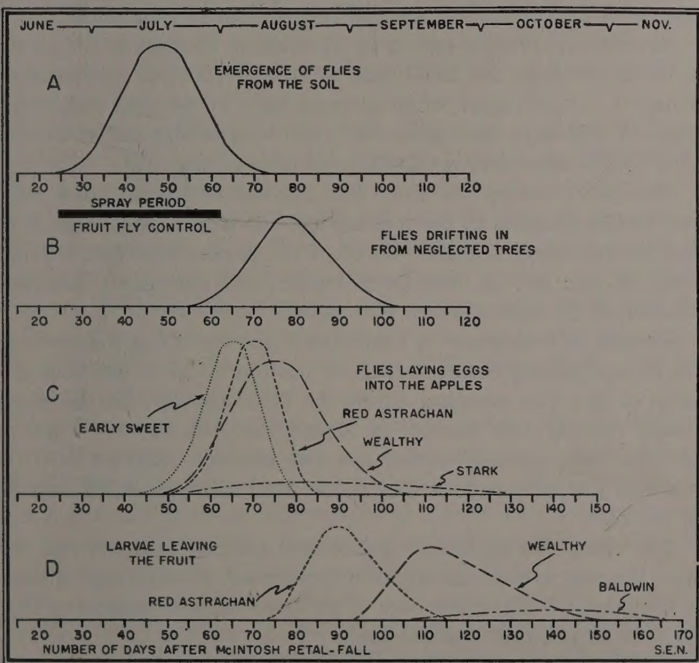


FIG. 2. Seasonal Cycles of the Apple Fruit Fly. The average number of days after McIntosh petal fall is shown under each section. The average calendar dates for Highmoor Farm are shown at the top of the chart.

Hibernation. The winter is spent in the pupal, or resting stage, in the soil. Porter (1928) reported from 87.9 to 98.4 per cent in the upper two inches of the soil, 99.2 to 99.5 per cent in the first three inches, and none below five inches. O'Kane (1914) reported 73.1 per cent of the puparia in the first two inches of sandy soil, and none below five inches.

Emergence of the Flies. The time of emergence of the flies is of critical importance in the application of insecticides for control of the fruit fly (see tables 1, 2, and 3, page 73, and table 10, page 79).

The emergence of the flies follows a definite seasonal pattern that varies somewhat in detail from year to year, but remains fundamentally constant. At the beginning of the emergence period, only a few flies appear each day, and the average number slowly increases daily through a period of about 10 days. Then there is a rapid increase, and large numbers of flies may appear daily through a period of two or three weeks, during which the important portion of emergence takes place. After this, emergence tapers off, and a very few flies may continue to emerge until cool weather in the fall puts an end to emergence.

Records, covering a period of 22 years at Highmoor Farm, show that, on the average, the flies began to emerge (0.1 per cent emerged) on June 30 (33 days after McIntosh petal fall), 50 per cent had emerged by July 19 (52 days after petal fall), and 99 per cent had emerged by August 13 (77 days after petal fall) (see table 1, page 73).

Emergence during the First and Second Summers. Most of the pupae remain dormant in the soil through one winter, to emerge as flies during the following summer. Some of the pupae, however, remain in the soil through two or even three winters, and emerge as flies during the second or the third summer (see table 3, page 73).

Records of emergence at Highmoor Farm show that the carry-over to the second summer varied from 4.51 per cent to 31.24 per cent of the number of flies that emerged during the first summer. On the average (8 years' records), the number of second-year flies was 11.71 per cent of the flies that emerged during the first summer. Dirks (1935) observed that the carry-over of flies to the third summer varied from 0 to 0.26 per cent.

The carry-over of flies to the second summer is important, for it enables the pest to continue to infest an orchard, even through a year of total crop failure. The carry-over to the third summer appears to be too small to be of practical significance.

Second Generation. That a few larvae transform into flies which emerge late in the same season in which the larvae enter the soil, thus producing a partial second generation, has been reported by several research workers. Phipps and Dirks (1933b) observed the emergence of a small number of second-generation flies during October, at Cumberland Center, Maine. No second generation flies were observed at Highmoor Farm. Because of the late emergence and the relatively small number of flies, it is evident that the second generation is of no practical importance in Maine.

Emergence of Males and Females. Research workers generally have observed that the female flies emerging in the observation cages somewhat outnumber the males. In the apple trees, however, more males than females usually are observed (Brittain and Good 1917, Caesar and Ross 1919, Porter 1928). Dirks (1935) in Maine, reported from 50.9 to 61.6 per cent of the emerged flies to be females. Of 12,982 flies that emerged in cages in 1950 at Highmoor Farm, 54 per cent were females.

Porter (1928) and also Phipps and Dirks (1933b) reported that female flies outnumbered the males, early in the emergence period, and males outnumbered the females late in the period. Phipps and Dirks observed that the male and female flies emerged in approximately equal numbers at the peak of emergence, when the greatest numbers of flies were emerging. These phenomena have been observed and confirmed repeatedly at Highmoor Farm.

Factors That Influence Emergence. There are a number of factors that influence the time when the flies emerge. Lathrop and Dirks (1945) showed that an important factor is the accumulated mean temperature from 30 days before McIntosh petal fall, until the time of emergence of any stated percentage of the flies. Rainfall during the same period also may have an important effect. The date of petal fall also was influential. The flies were observed to emerge earlier from light, sandy soil than from heavy, wet soil. Other conditions being equal, the flies emerge earlier in localities to the south and west of Highmoor Farm, and later to the north and east (see table 4, page 74).

That variations in sunshine and shadow striking the soil influence the time of emergence of the flies has been noted by previous research workers. Table 3 shows that in 1950, a rather typical season, the emergence of flies in shade followed about a week later than emergence in full sunshine. In that year there was practically no difference between the emergence of flies in full shade and in partial shade.

The emergence of flies during the first summer usually takes place earlier than the emergence of flies that have held over to the second summer. Table 3 shows that in 1950, emergence of the second-year flies followed the first-year flies by about 4 or 5 days.

Dispersion of the Flies. That the apple fruit flies can migrate considerable distances was observed by Phipps and Dirks (1932 and 1933a). In a study of the dispersion of marked flies released in neglected apple trees from which the fruit had been removed, many flies traversed a distance of 150 yards, and some, both males and females, were recovered as far as 212 yards from the point of release. In a somewhat similar study in Massachusetts, Bourne *et al.* (1934), captured a

marked fly 728 yards from the point of release. Observations at Monmouth suggest that the flies may disperse rather freely by following bushy fence rows, and along lanes of neglected apple trees.

Egg Laying. When the apple fruit flies emerge from the soil, they do not begin laying eggs immediately. Instead, they loiter in the apple trees or in any other trees or bushes in or near the orchard. Here the male and female flies mate, and live until the females are ready to deposit eggs in the apples.

Exactly how long a time elapses after emergence until the individual female begins to lay eggs is difficult to determine, and probably varies from 7 to 15 days, or longer. Detailed observations and egg counts were made at Monmouth in 1940, '41, and '42. In Wealthy apples, on the average, eggs first appeared in material numbers about 16 days after the flies began to emerge, and the peak of egg laying occurred about 30 days later, or about mid-August at Highmoor Farm. Egg laying in Red Astrachan apples started slightly later than in Wealthy, reached a peak slightly earlier, and continued through a much shorter period (see fig. 2). Observations indicated that the egg-laying period in McIntosh probably corresponded closely with the period in Wealthy. In Stark apples, egg laying began 5 to 7 days later than in Wealthy, and continued at a low rate over a long period with no definite peak.

Each variety of apples appeared to have a more or less definite period of attractiveness for the flies, evidently depending upon the degree of maturity of the fruit. Early apples, and especially early sweet apples are the first to attract the flies. As the early varieties ripen, they appear to become less attractive, and many of the flies drift to later varieties. The picking of the early apples, of course, hastens the drifting of the flies.

Hatching of the Eggs. Harvey (1890), in Maine, stated that the eggs hatch in 4 or 5 days. Porter (1928), in Connecticut, reported incubation periods ranging from 4 to 6 days, with an average of 4.5 days. Brittain and Good (1917), in Nova Scotia, observed the eggs to hatch in a minimum of 5 days, and a maximum of 10 days, with an average of 6.75 days. It seems probable that the length of the incubation period varies with the temperature prevailing at the time, being shortest during warm weather, and somewhat longer during cool periods.

Larval Activity. When the small larva emerges from the egg, it begins tearing the apple pulp by a continual motion of the head with its pair of strong, hooked teeth. The larvae do not grow rapidly, and make little progress through the apple until the fruit approaches maturity. Then, as the apple tissues begin to soften, the larvae grow rapidly and tunnel freely through the fruit. The full grown larvae leave the apples, and enter the soil, usually to a depth of a few inches, where they trans-

form to the pupal stage. The pupae remain dormant in the soil until they transform into adult flies.

The larvae begin to develop earlier, and become full grown first in the early-maturing apple varieties, followed in turn by larvae in the later-maturing varieties. Observations at Highmoor Farm (Dirks 1935) showed that larvae usually begin leaving Red Astrachan apples during the first week in August, leaving in greatest numbers during the last week or ten days in August and the first week in September. From Wealthy apples, the larvae begin to leave late in August, and leave in greatest numbers during the last half of September. From late varieties such as Baldwin, the larvae begin to leave during the second week in September. Comparatively few larvae have been observed to develop from the late varieties of apples, and the larvae leave in small numbers over a long period, without a definite peak.

CONTROL OF APPLE FRUIT FLY

Preventive Measures

In localities where the infestation has become excessive, it is difficult, and may be practically impossible, to obtain satisfactory control of the apple fruit fly by the use of insecticide applications, unless certain preventive practices are followed. Preventive measures, therefore, are of great importance in helping to keep down the development of an infestation in well-cared-for orchards, and to reduce the fruit fly population in orchards that have become severely infested.

Pick up Dropped Apples. It should be regular practice to pick up the dropped apples from the orchard floor, starting as soon as the apples approach maturity. The appearance of distinct larval trails in the dropped apples is a sign that the larvae soon will be leaving the fruit, and that the apples should be picked up.

The dropped apples should be gathered frequently until the crop is picked, so that no apples are left on the ground after the crop is harvested. Special attention should be given to picking up dropped fruit from under early and midseason apples, for they are especially likely to be infested and, potentially, are the greatest source of danger.

Disposal of Dropped Apples. As soon as the dropped apples have been gathered, they should be removed from the orchard, and disposed of promptly. The drops should be sorted, and any that are of value should be sold immediately, processed, or put into cold storage. The infested drops and others that are of no value should be buried promptly to a depth of at least 12 inches, or they may be dumped at some place a mile or two away from any orchard.

Elimination of Neglected Trees. Neglected apple trees are almost certain to become infested with fruit flies. Early, or midseason apples, especially, within two or three hundred yards of the orchard, may be an important source of infestation. Such trees should be properly cared for to reduce fly infestation, or they should be cut down.

The flies that drift into the orchard from neglected trees are especially dangerous because they are most likely to enter the orchard after the end of the spray season (fig. 2) when the trees are no longer well protected by a deposit of lead arsenate. Moreover, most of the drifting females have already fully matured, and are ready to deposit eggs immediately, before they can be killed by the insecticide.

The Use of Cold Storage. Harvey (1890) observed that when infested apples were held in an "ordinary ice chest," the development of the fruit-fly larvae was "arrested." Since that time, a number of studies have been made of the effects of cold storage upon fruit-fly infested apples. These studies were summarized by Chapman (1933). Chapman reported that all eggs and larvae were killed within about 35 days, when the infested fruit was held continuously at 32° F. Observations at Highmoor Farm showed that the progress of the injury was "arrested" when infested apples were held in cold storage. Injury continued to develop in similarly infested apples held out of cold storage. Cold storage, of course, did not remedy the injury done before the fruit was placed in storage.

In well-sprayed commercial orchards in Maine, fruit fly injury usually is very slight at picking time. By placing the apples in cold storage promptly, further injury often can be avoided. Of course, it is useless to place severely injured apples in cold storage.

Spray Practices for Fruit Fly Control. In past years, two applications of lead arsenate were recommended for fruit fly control, and usually proved sufficient in Maine commercial apple orchards, where fruit fly was held under complete control. In recent years there has been a tendency for many orchardists to make three or four applications of lead arsenate during the fruit fly spray period, partly to combat codling moth and other pests.

The factors that influence the effectiveness of insecticides applied for fruit fly control are complex and difficult to measure. Tables 5 to 12, pages 75-80, show the details of experimental tests conducted at Monmouth during the years 1947 to 1953.

Number of Applications. Table 11, page 79, shows that three or four applications of either dust or liquid spray reduced the infestation of fruit by as much as 64 to 87 per cent, even in the Frost Orchard, where fruit fly infestation had been allowed to build up over a period of years.

In 1953, unfortunately, it was not feasible to leave check plots, so the percentage reduction could not be determined. It seems evident, however, that three applications of liquid spray held the infestation in the Taylor Orchard (a well-kept commercial orchard) to a very low level (0.3 per cent of the apples). It is very probable that two, well-timed applications in the Taylor orchard would have resulted in very satisfactory control of fruit fly in 1953.

In deciding upon the number of applications to make, the grower should be guided by conditions in his orchard. If fruit fly is under complete control, two well-timed applications should be sufficient to prevent any rapid increase of infestation. Careful examination of the harvested apples should be made each year, and, if there is any increase of infestation, it may be advisable to make three or four applications the next year, to control the rising infestation.

Timing the Applications. In timing the applications, the object is to span the period of fly activity as completely as possible with the fewest number of applications.

The individual female fly may begin laying eggs in the apples from 7 to 10 days after she emerges. For several days after emergence begins, the number of flies emerging each day usually is small. Therefore, considerable numbers of eggs may not be deposited in the apples until at least 10 to 15 days after the flies begin to emerge. It seems advisable, however, to make the first fruit fly application soon after emergence begins, and thus give time for the insecticide to kill the flies before any eggs are laid in the apples.

The emergence of flies is observed at Highmoor Farm each year, and a notice is sent to the County Agricultural Agents as soon as emergence begins. If a grower does not have access to such observations, he probably should assume that the flies will begin to emerge in his orchard about 33 days after McIntosh petal fall.

Analyses of the arsenic deposits on apple leaves (see tables 8 and 9, pages 77-78), show that under ordinary conditions the deposit from an adequate application of lead arsenate apparently may be depended upon to remain on the trees in quantity sufficient to be toxic to the flies for a period of 10 to 14 days. Table 9 shows that the deposits, as applied by a modern mist-sprayer, were much lighter on the upper half of the tree than on the lower half. Because the apple fruit flies are rather active insects and move freely over the trees, probably the comparatively light spray deposits in the upper portions of the trees are of less consequence for fruit-fly control than they are for the control of other pests, such as the codling moth. It is important, however, for the grower to try to obtain reasonably uniform spray applications over the entire tree. Otherwise.

inadequate deposits in the top of the tree, and excessive deposits lower down, may result in poor pest control in the upper part of the tree and may increase the spray injury to leaves and fruit on the lower portions of the tree.

For fruit fly control, the trees should be sprayed often enough to maintain the protective spray deposit throughout the period of fly activity. In orchards where fruit fly has been kept under thorough control, a second spray, applied between 10 and 14 days after the first, should be sufficient.

Where fruit fly is a problem, and infestation needs to be reduced, three or four sprays may be necessary.

Especially where there is danger of flies drifting into the orchard from neglected trees, an application may be advisable during the last week of July. This application will serve to continue the protective spray deposit well into August, when danger from drifting flies is the greatest.

Avoid Excessive Spray Residue. Chemical analyses, as illustrated in table 12, page 80, show that when the apple trees are sprayed according to recommended practice for pest control in Maine, the arsenical residue on the fruit at picking time has not exceeded the tolerance permitted on apples. Growers should be careful not to apply excessive quantities of lead arsenate or other insecticides to their trees, especially late in the spray period. If proper applications have been made during the recommended spray period, it generally is not necessary to apply insecticides to the trees much after August 1. Growers should plan to avoid later applications of insecticides, for they may leave excessive residue on the fruit.

Lead Arsenate for Fruit Fly Control. Many insecticides have been tested for apple fruit fly control. Some have shown more or less promise. For a while it appeared that DDT might be effective, either alone or combined with lead arsenate. More thorough testing, however, showed that DDT is of doubtful value. As illustrated in tables 5, 6, and 11, pages 75, 76, 79, DDT added to lead arsenate dust, did not appear to increase the effectiveness of the treatment, compared to lead arsenate alone.

Considering economy, safety from plant injury, and its relation to the entire pest control situation, lead arsenate appears to be the most effective and generally satisfactory insecticide presently available for fruit fly control.

For fruit fly control, 15 per cent lead arsenate dust, or 3 pounds of lead arsenate in 100 gallons of standard liquid spray appears adequate. For concentrate sprays, the lead arsenate should be increased according to the concentration employed.

CODLING MOTH[3]

In former years codling moth has been considered a secondary pest of apples in Maine. Records of the "90-Per Cent-Clean Apple Club" show that 1.04 per cent of the tree-run, harvested apples from commercial orchards were injured by codling moth in 1932. Increasing attention to improved spray practices through the next 5 years, brought codling moth injury down to 0.11 per cent in 1937. During the past 5 or 10 years, however, codling moth injury has been increasing in Maine orchards. In a recent survey, many growers reported from 5 to 10 per cent of their apples injured by codling moth. The increasing infestation is probably, at least in part, the result of a series of comparatively mild winters and hot, dry summers, which have been favorable to codling moth activity.

Injury. Codling moth injury results from the attack of the larva (see fig. 3). The newly-hatched larva enters the apple by gnawing a small hole through the skin. Usually most of the larvae enter through the calyx, but many enter through the side of the fruit. Feeding and growing, the larva tunnels to the core, where it chews out a large dark brown cavity and devours the seeds. After ruining the inside of the apple, the full-grown larva emerges through a large, unsightly hole in the side of the fruit. It frequently happens that a codling moth larva dies very soon after it penetrates the skin of the apple. The resulting blemish usually is called a "sting."

CODLING MOTH

FIG. 3. Apple Injured by Codling Moth.

Life Stages. The *adult moth* is gray in color, tinged with somewhat iridescent brownish markings, leaving a lighter gray band across the middle of the insect when at rest with the wings folded. In this position, the moth is about 5/16 to 3/8 inch long. The *egg*, about 1/25 inch in diameter and difficult to see, is flat and pancake-shaped. It is nearly transparent at first, turning darker as the developing larva takes form inside. The *larva,* very small when it first hatches from the egg, is a

[3] *Carpocapsa pomonella* (L.)

pinkish-white caterpillar, with a brown head, and may be as much as ¾ inch long when full grown. The full-grown larva changes into the *pupa* or resting stage, which is somewhat shorter than the larva, slender and tapering toward the ends. It is glistening, chocolate-brown in color. The developing wings and legs of the adult are folded and delicately traced against the surface of the pupa. The adult develops from the pupa.

SEASONAL CYCLES

A careful study of the seasonal cycles of the codling moth was made by Siegler and Simanton at Winthrop, Maine, in 1913 and 1914. Observations made in more recent years have confirmed their results (see fig. 4).

Hibernation. The full-grown codling moth larvae spin their winter cocoons under loose bark on the trunks and large limbs of the apple trees, or in any other sheltered place near the infested trees. Some of the larvae remain in the apples until after harvest, and then emerge and spin-up for the winter in the apple boxes or in almost any place about the packing house. The larvae remain quietly in their cocoons through the winter.

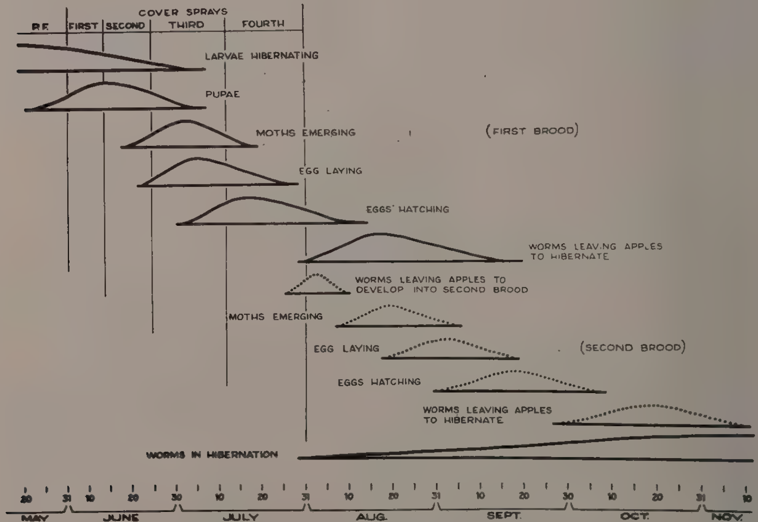


FIG. 4. Seasonal Cycles of the Codling Moth in Maine. The dates and the spray periods are approximately average for Highmoor Farm. Note that the critical times for applying the codling moth treatments occur at petal fall and again when the eggs are hatching, during the third and fourth cover spray periods.

Spring Activity Begins. Although pupation usually begins in May and extends into July, most of the overwintered larvae at Highmoor Farm change to the pupal stage during June.

Moths Emerge. The first brood moths usually begin to emerge about mid-June, and emerge in greatest numbers late in June and early in July.

Egg Laying. The moths begin laying eggs during the last half of June, and egg laying usually continues through most of July. Early in the season most of the eggs are laid near the apples, on the upper sides of the leaves or on the twigs or the fruit spurs. Later in the season, eggs are more likely to be laid on the apples.

Larvae Attack the Apples. As soon as the egg hatches the little larva makes its way to an apple, and starts digging in. The little larva discards the first few mouthfuls that it takes in digging through the skin of the apple. This habit probably saves some of the larvae from being killed by the lead arsenate spray deposit on the surface of the fruit.

Newly hatched larvae usually begin to attack the apples at Highmoor during the last week in June, or the first week in July, from 27 to 40 days after McIntosh petal fall. The greatest numbers of larvae enter the apples from the second to the fourth week in July, or 41 to 61 days after petal fall. Following the peak, decreasing numbers of larvae may continue to enter the apples through the rest of July and the first half of August. The time during which the newly hatched larvae are entering the apples, is the critical period for the application of insecticides in the cover sprays for codling moth control.

Larvae Leave the Apples. The full-grown codling moth larvae begin leaving the apples at Highmoor Farm during the last week or ten days in July, about 55 to 60 days after petal fall. The greatest numbers of larvae leave the apples during mid-August and they continue to leave, in decreasing numbers, during the rest of August and practically through the month of September.

Second Brood Develops. After leaving the apples, most of the larvae go into hibernation and remain quiescent throughout the winter. Some of the larvae—Siegler and Simanton (1915) observed 1 or 2 per cent—proceed with their transformations, however, and produce a second brood during late summer (fig. 4).

CONTROL OF CODLING MOTH

In combating codling moth, Maine apple growers should direct their spray programs at the destruction of the first brood. Normally, only a comparatively small second brood is produced in Maine, and if

the first brood is quite thoroughly destroyed, there will be practically no second brood produced in the orchard.

The Petal-Fall Application. The petal-fall application probably is the most important single application for codling moth control. From their experiments at Winthrop, Siegler and Simanton (1915) concluded that "one thorough spray application, as soon as the petals have fallen, is sufficient to control codling moth." The application should be made as soon as practicable after 90 per cent of the petals are off. The idea is to fill the calyx cups of the apples with the spray. Most of the first-brood larvae enter through the calyx, and if the calyx is well filled with lead arsenate, the entering larvae will be killed.

The Cover Sprays. The critical time for applying the cover sprays for codling moth control is during the period when the newly hatched, first-brood larvae are attempting to enter the apples. The critical period, at Highmoor Farm, begins during the last week in June, about 27 to 30 days after McIntosh petal fall, and continues through the month of July. Growers who have a codling moth problem should make every effort to keep their apples thoroughly covered by a protective film of lead arsenate during this critical period. The number of applications required will depend upon the weather and the severity of the codling moth infestation. Probably at least two applications should be made, and in some seasons, three or four applications may be advisable for complete protection. A few larvae may enter the apples during August, but the late July applications should destroy these stragglers. It is not advisable to apply insecticides much later than August 1, because of the danger of leaving excessive deposits on the harvested apples.

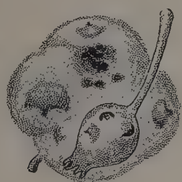
Spray tests at Monmouth, Maine, in 1951 and '52 showed that where lead arsenate was applied in the petal-fall spray and in two or three cover sprays, control of 97 to 99 per cent was obtained. The cover sprays applied for codling moth control are also important for the control of apple fruit fly, bud moth, and red-banded leaf roller.

The Insecticide to Use. The results of spray practices at Highmoor Farm, the experience of apple growers, and experimental tests, all indicate that in most Maine orchards, lead arsenate can be relied upon to control codling moth. In orchards where well-timed and thorough application of lead arsenate does not give satisfactory control, DDT should be added to the lead arsenate. Because DDT is destructive to many beneficial insects, however, it seems advisable to use it only when it is required, and to discontinue its use when the need has passed.

PLUM CURCULIO[4]

The plum curculio is a moderately destructive apple pest in the commercial apple orchards of Maine. It also infests the peach orchards of southwestern Maine, and cherries are attacked. Plums, both wild and cultivated, frequently are injured. Maine is near the northeastern limit of the range of plum curculio, and the pest generally is considerably less destructive here than it is in Massachusetts, or Connecticut, and in other areas farther south and west (Garman and Zappe 1929, Quaintance and Jenne 1912, Whitcomb 1929, Lathrop 1949).

Records of the "90-Per Cent-Clean Apple Club," from 1932 to 1937 show that, on the average, plum curculio injured from 0.14 to 0.74 per cent of the tree-run apples harvested from well-sprayed commercial orchards. On unsprayed check trees in experimental orchards in Monmouth, Maine, injury has been observed to range usually from about 5 per cent to 50 per cent of the picked apples.



PLUM CURCULIO

FIG. 5. Apples Injured by Plum Curculio. The small apple shows newly made egg punctures. The mature apple shows blemishes from old egg punctures, and late feeding punctures around the calyx.

Injury. The plum curculio injures the apples in several ways (see fig. 5). Early in the season, the adult curculio beetles, in feeding, gnaw through the skin of the young apples, and eat out small cavities beneath the surface. When the injured apples grow to maturity, the early-feeding punctures show as small, rounded, russeted areas.

The most typical and distinctive injury from plum curculio is produced by the egg punctures, or "stings," made on the young growing apples. The new egg puncture is a crescent-shaped incision, cut through the skin of the apple. As the apple grows, the punctures expand, to form more or less shield-shaped, russeted areas on the mature apples. Many of the injured apples become severely malformed before picking time.

[4] *Conotrachelus nenuphar* (Hbst.).

Many of the young, curculio-injured apples soon drop from the trees. Fortunately, however, most of the injured apples that drop off would be lost anyway, in the normal shedding of excess fruits from the trees (Detjen *et al.* 1942). This reduces the potential loss from curculio attacks.

Late in the season, the new curculio beetles of the fall brood feed upon the maturing apples. The late feeding punctures do not heal over, and they appear as small, dark-brown cavities around the calyx or, somewhat less frequently, about the stem of the mature apples.

Life Stages. In the course of its development, each plum curculio passes through several distinct forms or stages. The *adult curculio,* either male or female, is a dark brown, hard-shelled, snout beetle, about ¼ inch long. The adult curculios crawl and fly actively. Upon being disturbed by a slight jar, or upon being touched, the beetle has the habit of folding its legs against the body, and "playing dead." The small, light colored *egg* is laid just under the skin of the apple, in a crescent-shaped slit. The grub-like *larva* hatches from the egg, and feeds within the apple. The full-grown larva emerges from the apple, burrows an inch or two into the soil, and transforms into the *pupa* or resting stage. The adult, either male or female, develops from the pupa, and emerges from the soil.

SEASONAL CYCLES

Hibernation. The plum curculio beetles pass the winter in protected places such as bushy fence rows or old stone walls, and even hidden in the sod surrounding the apple trees.

Many of the curculios that go into hibernation in the fall die before spring arrives. In the peach-growing area of Fort Valley, Georgia, Snapp (1930) observed that an average of 66.9 per cent of the curculios, hibernating in Bermuda grass, lived through the winter. In Massachusetts, Whitcomb (1929) reported that an average of 25 to 40 per cent of the hibernating curculios survived the winter. At Monmouth, Maine, during seven winters—1936-43—from 0.4 per cent to 30.7 per cent of the curculios survived the winter. On the average, only 12.4 per cent of the curculios that went into hibernation in the fall, lived to emerge in the spring (Lathrop 1949). The high death rate during winter hibernation probably is the primary reason why plum curculio is less destructive in Maine than in areas to the south and west. It was found that survival was strongly influenced by precipitation and temperature during the hibernation period. The data showed that greater than average precipitation during January, February, and March is likely to be followed by increased survival of the curculios, and lower than average temperature

during December, January, and February is likely to be followed by decreased survival.

Emergence from Hibernation. Very early in the spring, some of the curculios become active on warm days, and return to protected places when the temperature drops. With the coming of continued warm weather, there is a general emergence from hibernation. On the average, emergence was observed to begin about 30 days before McIntosh petal fall, or about April 30 at Highmoor Farm. Fifty per cent of the curculios have emerged about a week before McIntosh petal fall, or about the third week in May, at Highmoor Farm. The curculios usually continue to emerge from hibernation for about two weeks after McIntosh petal fall, or until nearly mid-June at Highmoor Farm (see fig. 6).

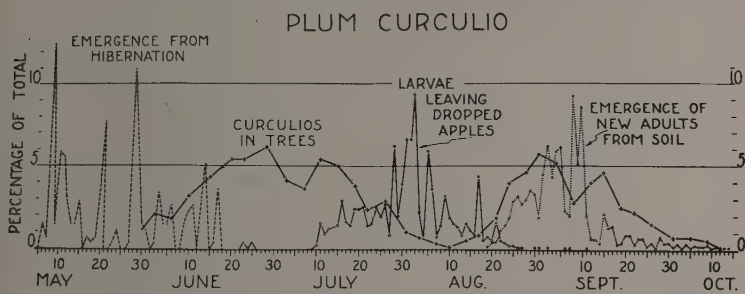


FIG. 6. Seasonal Cycles of the Plum Curculio at Highmoor Farm in 1939.

Spring-Brood Curculios in the Trees. Soon after the curculios emerge from hibernation, they fly to the apple trees. Usually the first of the curculios arrive in the trees during the "pink" blossom stage. Their numbers in the trees build up very rapidly about the time of petal fall. At Highmoor Farm, the curculios usually remain—in unsprayed trees—at or near maximum numbers through the last half of June. After the peak has passed, the number of curculios in the trees declines rapidly through the month of July.

Egg Laying. The curculio beetles begin laying eggs as soon as the apples begin to set and grow, usually within a week after petal fall. Egg laying proceeds rapidly, and the maximum numbers of eggs are found in the apples during the first half of July, or about 40 to 45 days after petal fall. After mid-July, the number of eggs declines rapidly through the rest of the month.

The first eggs usually are laid in the largest of the newly-set apples that are making most rapid growth. Temperature has an important influence, and a period of warm weather (daily maximum of 70° F. or higher) soon after petal fall, stimulates increased egg laying.

Larval Activities. As soon as the egg hatches, the young larva tunnels into the flesh of the apple. If the apple drops from the tree, the little larva continues to feed and grow. If the apple remains on the tree, and continues to grow, however, the curculio larva soon dies. The larvae continue to feed in the dropped apples for a period of two to four weeks, depending upon temperature.

When full grown, during July and August, the larvae leave the dropped apples, and descend into the soil, usually to a depth of one or two inches. In the soil, the larva changes to the pupa, or resting stage, and later, the pupa develops into a new curculio beetle.

Fall Brood of Curculio Beetles. During the last week of July or early in August, the new beetles of the fall brood begin to emerge from the soil, and fly to the apple trees. The fall brood curculios are found in the trees in largest numbers late in August and through about half of September. The curculio beetles feed for a while on the nearly mature apples, and then seek protected places where they spend the winter.

In Maine, curculios of the fall brood have not been observed to lay eggs, and no second brood of larvae is produced.

CONTROL OF PLUM CURCULIO

In Maine, a thorough application of lead arsenate (three pounds per 100 gallons of standard liquid spray, or 15 per cent lead arsenate dust) at petal fall, and again 7 to 10 days later, generally gives satisfactory control of plum curculio.

The object is to kill the adult curculio beetles soon after they come to the trees, and before the fruits have been injured. In the average season, there is a critical period of about 10 to 15 days after petal fall. During this interval, most of the curculios have gathered in the trees, but not many apples have been injured. It is during this critical period that insecticides are most effective. It should be realized that the behavior of the curculios varies somewhat from one year to the next, depending upon climatic conditions. A prolonged period of cold, wet weather following petal fall may delay the curculio activities, and may necessitate an additional application of lead arsenate for complete control. Unusually warm weather following petal fall may hasten egg laying, and thus may reduce the time during which insecticides can be employed effectively to protect the apples from injury.

Table 13 shows the results of some experimental applications against plum curculio. It appears, from the data presented, that liquid spray is somewhat more effective than dust. By making several, well-timed and thorough applications, however, dust can be effectively employed. In some applications, DDT was included primarily against

oystershell scale, but it does not appear to have been very effective against plum curculio.

The petal-fall application of lead arsenate appears to be the most important application against plum curculio. The application made 7 to 10 days after petal fall generally is important, and should not be omitted from the program where plum curculio is a problem. Applications made much later than 15 days after petal fall cannot be expected to be thoroughly effective, for unless earlier applications have been made, many of the apples probably will have been injured before that time.

Several of the new, organic insecticides have been tested against plum curculio on apples. Methoxychlor appears to be the most promising. It is somewhat more expensive than lead arsenate, however.

Prevention. A cleanup of bushy fence rows and other hibernation places in or near the orchard may help to reduce the curculio population. Neglected apple or plum trees near the orchard may support a large curculio population, and should be removed. Likewise, remove any orchard trees located in fence corners or other places where they cannot be sprayed thoroughly. Picking up and destroying the small, dropped apples in June and July is helpful in the home garden, but is hardly practical in the commercial orchard.

APPLE CURCULIO[5]

Through the years, apple curculio has ranked as a minor pest in most Maine apple orchards. In a few orchards in the southwestern part of the state, however, there have been outbreaks. In the heavily infested orchards, injury was severe, and the pest was difficult to subdue.

Injury. Like its relative, the plum curculio, the apple curculio injures apples by feeding, by egg laying, and by causing the fruit to be malformed. Besides injuring the fruit, the apple curculio beetles may also feed upon the developing leaf and blossom structures.

Both the feeding punctures and the egg punctures of the apple curculio usually develop into large, deep depressions or dimples in the surface of the mature apples (see fig. 7).

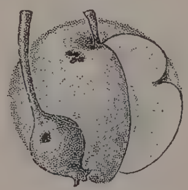


FIG. 7. Apple Injured by Apple Curculio. The small apple is injured by a new egg puncture. The mature apple shows an old egg puncture, and late feeding punctures near the stem.

Life Stages. Like the plum curculio, the *adult* apple curculio is a hard-shelled snout beetle, but it is lighter brown in color, and the snout is relatively much longer than that of the plum curculio. The *egg* is laid at the bottom of a small, deep cavity chewed into the apple by the female. The grub-like *larva* feeds within the apple until full grown, and then transforms into the *pupa* or resting stage, from which the new adult develops.

Seasonal Cycles. The adult apple curculio beetles hibernate over winter in protected places in and near the orchard. In a study of the pest in 1941 and '42, the adult beetles began to emerge from hibernation at Highmoor Farm during the second week in May, about 10 days before McIntosh petal fall, and about three weeks later than plum curculio. The adults continued to emerge from hibernation for about three weeks, or until about 10 days after petal fall.

The beetles fly to the apple trees where they feed on the young apples, and to some extent upon the developing leaves and blossoms.

[5] *Tachypterellus quadrigibbus* (Say).

The female apple curculio lays each egg at the bottom of a small, deep cavity which she gnaws into the apple. Most of the eggs are laid before the "June drop" is complete, but some egg laying continues until the apples are nearly half grown (Fulton 1928).

The eggs soon hatch, and the grub-like larvae feed within the apple until they are full grown. Most of the grub-infested apples turn yellow and drop from the trees. Some of the larvae complete their development in apples that remain on the trees until picking time.

The full-grown apple curculio larva transforms to the pupa within the apple, and later, the new adult emerges from the apple in which it developed. At Highmoor Farm, the new apple curculio beetles of the fall brood began emerging during the last week in July. By mid-August 80 per cent of the adults had emerged, but decreasing numbers continued to emerge through August and September.

The apple curculio beetles of the fall brood feed upon the nearly mature apples for a short time, and then go into hibernation. No eggs are deposited in the fall, and there is only one generation a year.

Control of Apple Curculio. An outbreak of apple curculio is difficult to bring under control by means of arsenical sprays. Apparently, however, the regular application of lead arsenate, as recommended for plum curculio, generally prevents the build-up of severe infestation of apple curculio. Probably some of the new organic insecticides will prove effective against outbreaks of this pest.

Cleaning up hibernation quarters, and the removal of neglected apple trees is important for keeping down apple curculio infestation. This pest is likely to build up on hawthorn (*Crataegus* spp.), and these bushes in or near the orchard should be removed. Gathering and destroying the dropped apples is important in the home garden.

EUROPEAN RED MITE[6]

During the past 15 years, the control of European red mite has become an increasingly difficult problem throughout the apple-growing sections of Maine. Apparently the increased difficulty is correlated with the greater number and thoroughness of sulphur applications for the control of apple scab. In experimental orchards, it has been observed repeatedly that well-sprayed trees often were severely infested, while adjacent, unsprayed trees were practically free from mites. It seems probable that the sulphur fungicides destroy many of the natural enemies that help to keep the mites under control.

Injury. Leaves infested with European red mites lose much of their green color, and take on a sickly brownish or "bronzed" tinge. Mite injury usually becomes evident first on the small, "primary," leaves near the base of the current season's growth, and especially on the leaves well back inside the tree. Later, as the mites multiply and spread, the younger, larger "secondary" leaves may be injured. The outermost leaves, near the growing tips, seldom show severe injury. On severely infested trees, most of the mature leaves may be affected, however, and the bronzed appearance of the mite-injured trees can be observed readily, even from a considerable distance.

EUROPEAN RED MITE

FIG. 8. European Red Mite on Apple Leaf. The magnified section shows mites and eggs on the underside of the leaf.

The fundamental injury to the mite-infested leaves is the destruction of the green chlorophyll, which, of course, is essential to the growth and productiveness of the trees (Lathrop and Hilborn 1950, Lathrop 1951, Chapman, Lienk, and Curtis 1952). It has been found that leaves from severely infested trees may lose as much as 30 per cent of the chlorophyll. Under some conditions, the loss of chlorophyll may be correlated with a reduction in the size and color of the fruit at picking time. Severe infestation early in the season may affect fruit bud formation, and thus reduce the crop the following year (Garman and Townsend 1938).

[6] *Paratetranychus pilosus* (C. & F.).

As observed in the orchard, much of the injury usually ascribed to red mite activity results from the combination of red mite damage and sulphur spray injury, aggravated by sunshine and high temperature. It is difficult to determine exactly the full extent of the injury caused by mites, and just how much should be ascribed to spray injury and to sunburn.

Research workers generally have reported that many leaves may drop from trees severely injured by mites, the apples may drop before maturity, or the fruit may be reduced in size, and may be poorly colored at picking time. At Manchester, Maine, in 1943, a severely infested McIntosh apple orchard was observed, in which the trees were largely defoliated, and many of the apples dropped. Garman and Townsend (1938) reported similar effects from red mite infestation in Connecticut orchards.

Climatic variations and orchard conditions may influence the degree of injury resulting from red mite attacks. Newcomer and Yothers (1929), in the Pacific Northwest, observed that in irrigated orchards, the leaves seldom drop, but in non-irrigated orchards complete or partial defoliation frequently results from severe red mite infestation. In western New York, Chapman, Lienk, and Curtis (1952) observed no dropping of the leaves, and no reduction in the color of the fruit as a result of red mite infestation on young Cortland apple trees in their experimental plots. They did suggest, however, that the mites could reduce the crop by interfering with setting of the young apples.

Even though it may be difficult to estimate the extent of injury caused by the European red mite, Maine growers generally regard it as a potentially destructive pest that needs to be kept under control if the orchard is to be maintained in a highly productive condition. The problem is to control the mites in the most effective and economical manner.

Kind of Trees Attacked. In Maine, the European red mite is primarily a pest of apple trees. Red Delicious and Golden Delicious apples appear to be the varieties most susceptible to severe injury. McIntosh also suffers severely from red mite injury. In Connecticut, according to Garman and Townsend (1952), Baldwin and Delicious are varieties preferred by the mites. Newcomer and Yothers (1929) state that the favorite food plants are the common deciduous fruits, especially plum, prune, apple, and pear. They list a number of other plants on which the mites have been found.

Life Stages. The *adult female* of the European red mite is very small, scarcely more than 1/90 inch in length. Viewed through a strong lens, the mite is seen to be stout-bodied, almost as wide as long, with four rows of rather strong, somewhat curved, bristles arising from the

upper surface of the body. It has eight legs[7] with which it crawls actively. The color of the female varies from deep velvety red to brownish. There is a white dot at the base of each of the body bristles. The adult females lay eggs to produce the next generation.

The *adult male* is considerably smaller than the female; the body is somewhat more slender, and the legs are proportionally longer. In color, the male is pale brownish.

The *egg* is rounded, nearly spherical, and slightly flattened. By careful examination under a strong lens, a slender stalk or bristle, about as long as the diameter of the egg, can be seen arising from the top of the egg. The newly deposited egg is bright red in color, but darkens somewhat as the embryo develops.

The *larva* hatches from the egg. It is yellowish or orange when first hatched, but changes to reddish brown after feeding. The larva has six legs, crawls actively, and feeds upon the chlorophyll of the infested foliage. After a period of feeding, the larva becomes quiet, sheds its skin and changes into the protonymph.

The *protonymph* has eight legs. It feeds and grows, becomes quiet and sheds its skin to transform into the deutonymph.

The *deutonymph* is the first stage in which the male can be distinguished from the female. After feeding and growing, it passes through a quiet period and transforms to the adult. The adult males and females mate, and egg laying begins soon thereafter.

SEASONAL CYCLES

The European red mite spends the winter in the egg stage on the bark of twigs and branches of the infested trees. There is a tendency for the mites to place the eggs in the protection of small irregularities in the tree bark. Many eggs frequently are grouped on the bark below the junction of a branch or twig, and more eggs usually are laid on the lower side of a branch than on the upper side. Sometimes small areas of bark may be reddened by a multitude of eggs. In Maine, however, dense groups of eggs seldom, if ever, cover large areas of bark, even on trees that have been severely infested with red mites.

The overwintered eggs begin to hatch just before the McIntosh apple blossoms reach the pink stage, and hatching is practically complete by the time of petal fall.

The newly-hatched mites immediately crawl to the leaves, and begin feeding. Generally the mites are found on the undersides of the

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[7] In the adult stage, mites have eight legs, and technically are not insects. Adult insects have six legs.

leaves. On cool, cloudy days many mites may be found on the upper sides of the leaves. Sometimes, on severely infested trees, the mites may be found crawling on the stems, branches and fruit. Probably little, if any, feeding is done except on the leaves.

At Highmoor Farm, the mites have been observed to mature and begin laying eggs as early as 7 days after petal fall. Through the rest of the season, the mites continue to live and multiply on the apple trees. The number of generations that occurs annually varies with the locality and climatic conditions. In Virginia, Cagle (1946) reported ten generations, but the tenth consisted mostly of winter eggs. Newcomer and Yothers (1929) at Yakima, Washington, observed eight generations, of which the last two were incomplete. Garman (1923) estimated that there may be as many as six generations in Connecticut. Gilliatt (1935) in Nova Scotia, observed five generations, of which the last three were incomplete. No careful rearing was conducted to determine the number of generations that occur in Maine. Observations at Highmoor Farm indicate that there probably are four generations, with the last two cut short at the end of the season, and possibly the beginning of a fifth generation.

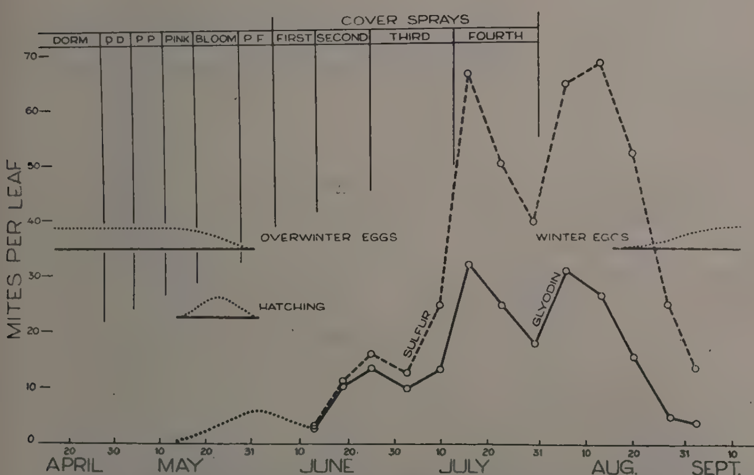


FIG. 9. Seasonal Cycles of the European Red Mite. The dotted line shows the course of mite infestation from the time the overwintered eggs begin to hatch until the new mites begin to multiply. The broken line shows the population of mites on trees treated with sulphur through the season. The solid line shows the population on trees treated with glyodin ("341") after bloom. Frost Orchard. 1951.

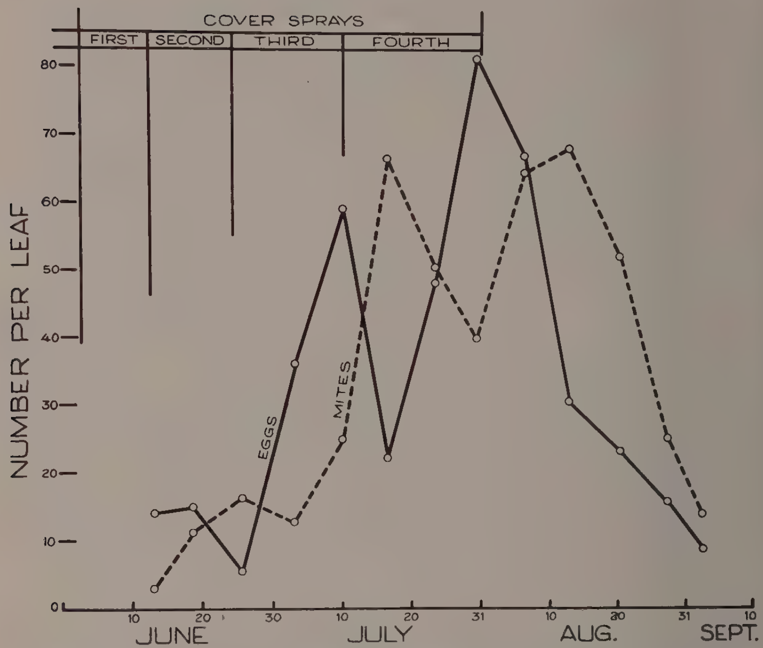


FIG. 10. European Red Mite. Populations of mites and of eggs on secondary leaves from trees sprayed with sulphur through the season. Frost Orchard, 1951.

The exact number of generations during the season, however, appears to be of little or no practical significance, for the generations overlap. After the first mites mature, eggs and mites in all stages of development are present on the leaves through the rest of the season until cold weather stops activity in the fall.

As observed by Lathrop and Hilborn (1950) in Maine, and by Chapman and Lienk (1950) in New York, the European red mite population on severely infested apple trees passes through a characteristic seasonal pattern (figures 9 and 10). As the overwintered eggs hatch, the mite population on the leaves increases until about the time of petal fall. Then for a period of about two weeks, as the mites die or are destroyed by natural enemies or adverse weather, the mite population declines to a low point late in June. As the mite population declines during the last half of June, the number of first-brood eggs on the leaves increases.

Early in July, as the first-brood eggs hatch, there is a rapid increase

in the population of mites on the trees. Late in July or early August, the mite population reaches a peak that may rise and fall more or less through most of August. During the last half of August and through September, the mite population declines rapidly, although a few mites may remain on the leaves until they are killed by freezing temperatures.

There appear to be several factors responsible for the decline of the mites during late summer. The severely injured apple leaves become unattractive to the mites, and even the healthy leaves are changed in character as fall approaches. The populations of predators that feed upon the mites, are likely to build up on the heavy infestations in midsummer. Beginning in mid-August, an increasing number of the female mites deposit overwintering eggs that will not hatch until the next spring.

Sometimes, where the infestation is light, the mite population may not follow the pattern described. Instead, there may be a gradual rise through the summer, continuing nearly to the end of the season.

CONTROL OF EUROPEAN RED MITE

Maine apple growers generally depend upon two methods of attack for combating European red mite:

1. Delayed-dormant oil spray to destroy the overwintered eggs.
2. Summer spray applications to reduce mite infestations.

Delayed-Dormant Oil Spray. Oil spray, applied in the delayed-dormant period, has been used for the control of European red mite in Maine for many years. Experience in the experimental orchards at Highmoor Farm, as well as observations in commercial apple orchards, has shown that the thorough and well-timed application of a high quality oil spray, probably is the most effective method for combating European red mite.

Satisfactory mite control from the use of an oil spray requires attention to a number of important details.

1. Thorough application is essential. The object is to wet completely every part of the tree, from the ground to the tips of the smallest branches. If any part of the tree is missed, mite control may not be adequate. In the past, the best practice has been to have one man spray from the ground, and another spray from the top of the spray tank.

Brann, Avens, and Dean (1948) in New York, have done some pioneer work on the application of dormant oils as mist sprays. At Highmoor Farm, effective applications of delayed-dormant oil have been made as air-blast mist sprays at 2x concentration, with no apparent injury to the trees. The main difficulty has been to obtain complete and uniform wetting over the entire tree.

2. Timing the delayed-dormant oil spray is important for mite control. Chapman and Pearce (1949) by careful laboratory experiments showed that the egg-killing efficiency of the oil spray was approximately doubled when the spray was applied 20 days before the mite eggs hatched, compared to spray applied 40 days before the hatch. It has been noticed at Highmoor Farm that oil spray applied late in the delayed-dormant period gave more complete control than spray applied early in the period. Of course, the oil spray should not be delayed too long, because of danger of injury to buds that are too far advanced when the spray is applied.

3. The quality of the oil is important. Pearce, Chapman, and Avens (1942) published specifications for "superior" oil spray, which they found to give the highest egg-killing efficiency. The spray oils generally sold by reliable dealers in Maine, when properly applied, appear to give satisfactory kill of red mite eggs.

Probably the most frequent objection to the use of the delayed-dormant oil spray for red mite control is the difficulty often encountered in driving the sprayer through the orchard early in the spring. Another objection is the comparatively short period during which the delayed-dormant spray can be applied for best results. Perhaps both of these objections can be relieved to a considerable extent if an air-blast mist spray can be generally used for the delayed-dormant oil application. The use of an air-blast mist sprayer requires much less water to cover a given acreage. Therefore such spray equipment can be used more easily during a period when the orchard floor is too soft for heavier equipment, and the orchard can be sprayed much more rapidly than is possible with the conventional, liquid sprayers.

Summer Treatments for Red Mite Control. When a severe infestation of European red mite develops during July or early in August, it may become necessary to apply a treatment to reduce the infestation. There are several acaricides available. The summer dinitro compounds, DN 111 spray and D 4 dust, probably were the first successful acaricides developed for summer application. These dinitro materials are still valuable acaricides. They may cause injury to fruit or foliage if used too soon after petal fall, or during periods of high temperature. The organic phosphates, tetraethyl pyrophosphate, and parathion have been used effectively as summer acaricides. These materials are more or less dangerous to use, they have comparatively short residual effects, they are likely to injure the apples, and they may destroy many natural enemies. "Ovotran" (p-chlorophenyl p-chlorobenzene sulfonate) and some other new acaricides have been reported to give good results.

These materials are comparatively new, and their value and limitations are not yet fully understood.

Timing the Summer Treatment. If red mite infestation was severe during the preceding summer, and the delayed-dormant oil spray was not applied during the current spring, the grower may decide that an early acaricide application is advisable. Soon after petal fall, there usually is a short time when practically all of the over-wintered eggs have hatched, very few new eggs have been deposited, and the red mite population has not yet started to build up rapidly. The thorough application of an effective acaricide soon after petal fall, therefore, may set back the mite infestation sufficiently so that no further treatment will become necessary during the season. If important red mite injury does not develop during July or early in August, probably no treatment will be necessary, for an infestation after mid-August causes comparatively little injury to the tree.

When a mite infestation builds up during July, it probably is advisable to make a prompt application of an acaricide. With an effective acaricide, the problem is to obtain thorough coverage, especially on the undersides of the leaves, where most of the mites are located. It seldom is possible to stop a severe red mite infestation with one application of an acaricide and a repeat application may be advisable after an interval of 7 to 10 days.

Relationships of Red Mite and Scab Control. A number of research workers (Garman and Townsend 1938, Pickett *et al.* 1946, Lord 1949, Lathrop and Hilborn 1950, Hilborn and Lathrop 1951) have observed that sulphur fungicides, and especially sulphur dust, destroy many of the predaceous enemies of the European red mite, and thus promote increased red mite infestation. In the past, sulphur fungicides have been essential for apple scab control, and sulphur still remains a valuable fungicide. The control of European red mite, therefore, has become closely interrelated with the problem of scab control.

The most critical time for scab control in Maine apple orchards generally occurs between the delayed-dormant period and petal fall. If scab has been controlled thoroughly during this early period, it generally can be held under control through the rest of the season by means of a comparatively weak fungicide. Except for the delayed-dormant oil application, the critical period for red mite control in Maine orchards occurs from petal fall through the rest of the season.

A search, therefore, has been made for a fungicide that would be sufficiently effective to control scab, at least during the post bloom period, and that would not promote red mite infestation. Two promising materials have been found (Hilborn and Lathrop 1951) and are being

tested by the Maine Experiment Station. One of the promising materials is glyodin.[8] The other is "Karathane," [9] in which the active ingredient is dinitro capryl phenyl crotonate.

Experiments with Glyodin

Experimental tests with glyodin conducted in 1951, '52, and '53 are discussed here in some detail. The tests were conducted in the Frost Orchard each year, and also in the Taylor Orchard in 1953.

The Frost Orchard consisted of 121 trees about 35 years old, mostly McIntosh, with a few Red Delicious scattered through the planting. Each year the entire orchard was sprayed and dusted until bloom. Then the orchard was divided into four plots, and through the rest of the season, alternate plots were treated either with glyodin or with sulphur as a fungicide (see fig. 11 and tables 14, 15, 16, pages 81-82).

The experimental block in the Taylor Orchard consisted of 200 trees about 15 years old, including McIntosh, Red Delicious, and Spy varieties. The block was treated as a unit until bloom, and then divided into two approximately equal plots. Through the rest of the season, one plot was treated with glyodin and the other with sulphur as a fungicide. The experimental spray program in the Taylor Orchard was the same as in the Frost Orchard in 1953, except that the delayed-dormant oil spray was applied in the Taylor Orchard, and not in the Frost Orchard.

Results of the experiments were determined by counting the mites on the leaves, by measuring the chlorophyll content of the leaves, and by comparing the weights of random samples of apples picked from the two treatments.

The data from the Frost Orchard each year showed reduced mite populations on the plots treated with glyodin after bloom, compared with the populations on the plots treated with sulphur through the season (see tables 17 to 23, inclusive, pages 83-87). In 1952, in an effort to offset any error that may have arisen from the locations of the treatments within the orchard, the positions of the plots treated with glyodin and with sulphur, respectively, were reversed from the arrangement used in 1951. The mite populations on trees treated with glyodin continued to be reduced in comparison with the sulphur-treated plots. The Frost Orchard was never sprayed with oil, and even on the glyodin plots, the mite population was higher than would be tolerated in a commercial orchard. The small size of the plots permitted considerable drift of

[8] Crag Fruit Fungicide 341, containing glyodin, is manufactured by Carbide and Carbon Chemicals Company.

[9] Karathane is manufactured by Rohm and Haas Company.

spray from one treatment to another, and drift of mites also, thus minimizing the differences between the two treatments.

In a test at Highmoor Farm, a comparatively large block of trees was sprayed with oil in the spring of 1951. Each year the block was treated with sulphur through bloom, and with glyodin after bloom. The oil spray was not repeated, and no other treatment was applied for mite control. The average maximum counts were as follows: 1951, on

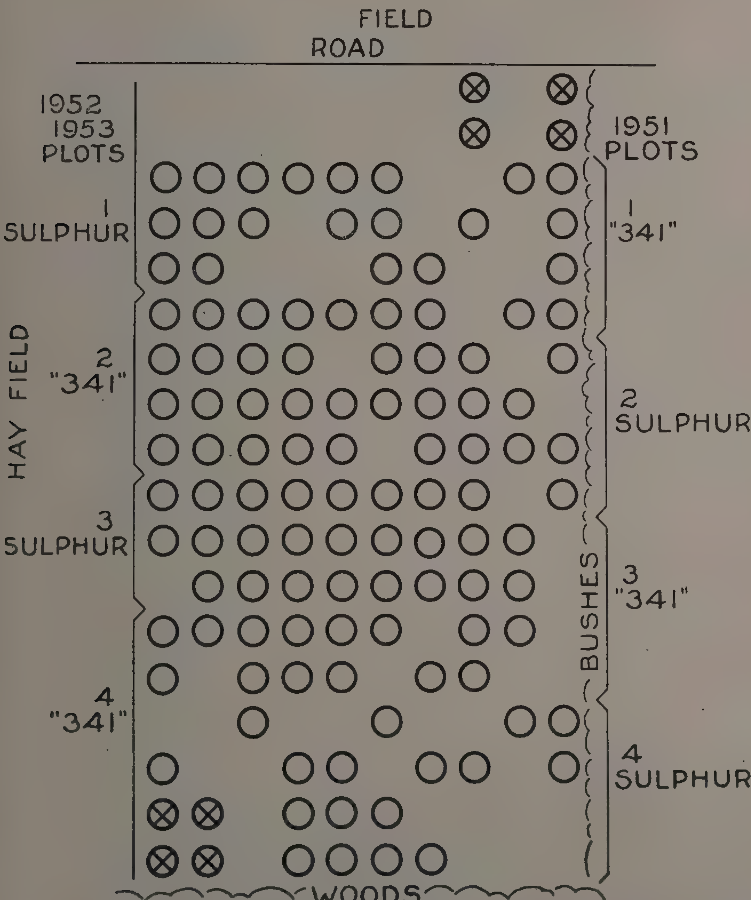


FIG. 11. Arrangement of the Spray Plots in the Frost Orchard. Notice that the positions of the treatments were reversed in 1952 and '53 from the positions in 1951. Check trees, indicated by X, received no spray applications after bloom in 1951 and '52. No check trees were left in 1953.

primary leaves 0.88 mite and 2.91 eggs per leaf; in 1952, on primary leaves 1.62 mites and 3.28 eggs, and on secondary leaves 1.44 mites and 2.89 eggs. In 1953, the count was 0.38 mite and 1.04 eggs on primary leaves, and on secondary leaves it was 0.37 mite and 0.67 egg. No mite injury developed on the trees, and no acaricide was applied in 1951, '52, or '53. In the spring of 1954, DDT was applied in the pink spray for leafhopper control, and the mite population increased during July. An acaricide was applied during the first week in August.

In commercial orchards where growers have used glyodin and no sulphur after bloom, generally no other treatment has been necessary for mite control, but it often has been necessary to apply treatments for mite control on nearby trees treated with sulphur.

The question arises as to whether glyodin has a definite acaricidal action, or if the reduction of the mite populations results from the activities of natural enemies. Delayed-dormant oil spray was applied in a test conducted in the Taylor Orchard in the spring of 1953. Very few natural enemies were observed in either the sulphur plot or the glyodin plot during that summer, but the mite population built up more rapidly on the trees treated with glyodin. Apparently sulphur was somewhat more effective than glyodin as an acaricide, and in the absence of material numbers of natural enemies in either plot, the mites increased more rapidly in the glyodin plot.

Table 25 shows that each year the chlorophyll content of the leaves sprayed with sulphur was less than that in leaves sprayed with glyodin. The reduction of the chlorophyll probably was due partly to mite injury, and also partly to sulphur spray injury. This appears to be confirmed by the 1953 test in the Taylor Orchard and by Garman, Keirstead, and Mathis (1953) in Connecticut. Although the mite count was somewhat higher on the glyodin plot, the chlorophyll content of the leaves was 10 per cent higher than that of the leaves in the sulphur-sprayed plot. Conversely, the mite count was lower in the sulphur-sprayed plot but there was a resultant reduction of 10 per cent in the chlorophyll content of the leaves.

It is especially interesting to note that the reduced chlorophyll content of the leaves was associated with a reduction in the weight per 100 apples at picking time. The reduction in the weight of the apples, shown in table 24, possibly was no greater than might be accounted for as experimental error. The consistency of the difference in weight of the random samples, however, strongly suggests that there was a correlation between the decreased chlorophyll content of the leaves, and the size of the apples.

For scab control glyodin appeared to be at least as effective as the

mild sulphur sprays (Hilborn and Lathrop 1951). In the tests reported here glyodin used after bloom gave excellent scab control compared to wettable sulphur sprays after bloom.

In 1951, the dosage of glyodin probably was excessive, and severe russet occurred on many of the apples. In 1952 and 1953, the dosage of glyodin was reduced and a small amount of lime was added to the spray with the result that no material amount of russet was observed on the apples.

Experiments with Karathane

In tests conducted in 1948 and 1949, Lathrop and Hilborn found that Karathane (formerly known as Arathane) gave excellent control of European red mite and scab control practically equal to that of mild sulphur. The appearance of the foliage on the Karathane plots was excellent. The chlorophyll content was high compared with the sulphur-sprayed foliage. Commercial growers, who conducted cooperative tests, also found Karathane very promising. Unfortunately, the manufacturers withdrew the material from commercial production, and it was not available again even for experimental tests until 1954.

In a test in the Taylor Orchard in 1954, Karathane was used in all applications after bloom. The Karathane-sprayed foliage appeared excellent, and the red mite population was held to a very low level. Scab control was satisfactory. Karathane appears to be a very promising combination acaricide and fungicide, if it becomes available commercially at a reasonable price.

Natural Enemies

A number of careful studies have been made of the natural enemies of the European red mite (Newcomer and Yothers, 1929; Gilliatt, 1935; Garman, 1923; Garman and Townsend, 1938). In Maine observations have been made of natural enemies in connection with experiments on the control of the red mite, but no extensive detailed studies have been made. A number of predaceous species have been observed, of which the small, black, lady beetle *Stethorus punctillum* Ws.[10] appeared to be the most effective in reducing red mite populations. Dr. Sabrosky[11] states that this species was imported from Europe, and differs slightly from the native American species *S. punctum* Lee. *S. punctillum*, in both the larval and adult stages, was observed to prey upon the mites and their eggs. Apparently this lady beetle is very sensitive to sulphur

[10] Determined by courtesy of Curtis W. Sabrosky.

[11] Letter of December 13, 1950.

applications, and seldom was observed in orchards treated with sulphur after bloom. Sulphur dust is especially destructive to this predator, and it seems advisable to avoid sulphur dust as much as practicable even in the early applications before petal fall.

Two species of thrips,[12] *Leptothrips mali* (Fitch) and *Haplothrips* sp., probably *faurei* Hood, were observed frequently. The thrips, both adults and nymphs, attacked the mites, but appeared to be especially effective in destroying the eggs. These thrips appeared to be somewhat resistant to sulphur applications, and were observed more frequently than *S. punctillum* on trees that were sprayed with sulphur through the season.

The anthocorid bug, *Orius (Triphleps) insidiosus* Say, was observed occasionally on the mite-infested leaves, and probably was a factor in reducing the mite populations. It appeared to be much less important, however, than the black lady beetles or the thrips.

The larvae of the two-spotted lady beetle, *Adalia bipunctata* (L.), were observed attacking the mites. This species, as well as other large lady beetles, appeared to be attracted to the green apple aphid rather than to mites.

Small cecedomyid larvae were observed occasionally attacking the mites.

Most of the publications on the subject list the predaceous mites as important enemies of the European red mite. In Maine orchards infested by red mites, occasional specimens of the predaceous mites were observed, but they did not appear to be numerous enough to have much effect upon the red mite population.

Sulphur appears to be much more destructive than glyodin to the natural enemies of the European red mite. Of course, it should not be assumed that sulphur destroys only the natural enemies, or that glyodin in some way avoids injury to the natural enemies. In recent years it has become increasingly clear, however, that most insecticides are more or less selective in their action. That is, any insecticide is effective against certain susceptible insects, but is less effective against other insects which are resistant to the insecticide. Apparently it happens that many of the natural enemies are more susceptible to sulphur than are the red mites. It seems, however, that glyodin, a good fungicide, probably has little or no insecticidal effect, either upon the mites or their natural enemies. The selective action of the two materials was emphasized in the summer of 1953, when an infestation of the white apple leafhopper built up on all of the experimental plots sprayed with glyodin after bloom, while there was comparatively little infestation on any of the

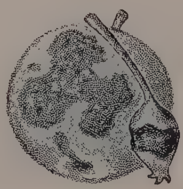
[12] Determined by Kellie O'Neill.

plots sprayed with sulphur through the season. The selective action of the various spray materials that have been developed for use in apple orchards, presents a difficult problem for the apple grower, but it also presents valuable opportunities for the most effective use of insecticides and fungicides in developing the spray program.

GYPSY MOTH[13]

When Maine woodlands become infested with gypsy moth, nearby orchards are likely to be invaded. If the orchard is not properly sprayed, the gypsy moth caterpillars may cause severe injury to leaves and fruit. A great outbreak of gypsy moth began about 1935, and reached a maximum of destructiveness during the summers of 1939 and 1940. The outbreak subsided in 1941 and 1942. Gypsy moth infestation in Maine remained comparatively low until 1952, when there was another great increase. In the summers of 1953 and 1954, Maine suffered from one of the most severe and widespread outbreaks of gypsy moth ever experienced in this State.

Injury. Though gypsy moth is primarily a woodland pest, apple is one of its favorite food plants, and apple trees that have not been properly sprayed may be severely injured. The injury is caused by the feeding of the larvae (caterpillars) on leaves and fruit. Where infestation is



GYPSY MOTH

FIG. 12. Apples Injured by Gypsy Moth Larvae. The small apple shows a fresh feeding scar. The mature apple shows typical, large russeted areas that develop from the early feeding scars.

severe, apple trees may be completely stripped of leaves. The larvae eat large, deep cavities in the young apples, and many of the injured fruits soon drop. Injured apples that remain on the trees until picking time are marked by large, unsightly russeted blemishes. Unless proper and timely sprays are applied, a large proportion of the apples may be ruined.

Life Stages. The *male* gypsy moth measures about 1½ inches across the outspread wings. It is deep brown in color, with a darker pattern of irregular stripes across the wings. The male is a strong flier, and frequently may be seen flying, even during the day.

The *female* moth is about 2 inches across the outspread wings. In color, the female is nearly white, tinged with buff, with an irregular pattern of dark markings across the outspread wings. Although the wings appear to be well developed, the female gypsy moth does not fly.

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[13] *Porthetria dispar* (Linnaeus).

The *eggs* are laid in masses placed on tree trunks, stone walls, or on any place where the female moth happens to emerge from the pupa. The egg mass is oblong in shape, varies from ½ inch to about 1 inch in length, and may contain several hundred eggs. The mass is covered with a dense mat of moth hairs having the color of chamois skin.

The *larva,* or caterpillar, is small, ¼ inch or less in length, when it hatches from the egg. The small larvae spin long, silken threads which are taken up by breezes and air currents, floating the little caterpillars long distances. Because the female gypsy moths do not fly, dispersal of the species is accomplished largely by the air-transported larvae. After the larva grows, and sheds its skin for the first time, it becomes too large and heavy to float on its silken thread.

The full grown gypsy caterpillar reaches a length of 2½ inches. It is dark brown in color, with a double row of dark blue spots on the back, toward the head-end of the body, followed by a double row of dark red spots farther to the rear. The full grown larvae become somewhat restless. They go down the tree trunk, and frequently crawl short distances to nearby objects where they transform to pupae.

The *pupa,* or resting stage, is formed in a very flimsy silken cocoon. The pupa is about 1 inch long, dark brown, sparsely set with short, yellow hairs. After about 10 days, the adult moth, male or female, emerges from the pupa.

SEASONAL CYCLES

The winter is spent in the egg stage. The eggs begin hatching two or three weeks before McIntosh petal fall, or from about the first until the middle of May at Highmoor Farm. The great bulk of the eggs hatch before McIntosh apple trees come into bloom. At first, the little larvae are sluggish, and are likely to remain close to the egg mass from which they hatched. It is not until about two weeks after hatching, that the young larvae begin drifting in the breeze (see fig. 13). This agrees with observations reported by Collins (1915). At Highmoor Farm, considerable numbers of the little larvae begin drifting in the air, and settling into apple orchards during the "pink" blossom stage. Great numbers of the young gypsy larvae drift into the orchards, from infested woodlands, during the period of apple bloom. By the time of petal fall, most of the larvae have grown too large and heavy to float on their silken threads, and very few of the small caterpillars drift into the orchards after petal fall (Lathrop 1940).

On unsprayed trees, the gypsy caterpillars feed greedily on leaves and fruit. They grow rapidly, and by the middle of July, at Highmoor Farm, the larvae are reaching full growth and beginning to pupate. Many

moths appear during the last half of July, and most of the eggs are deposited during late July and early August.

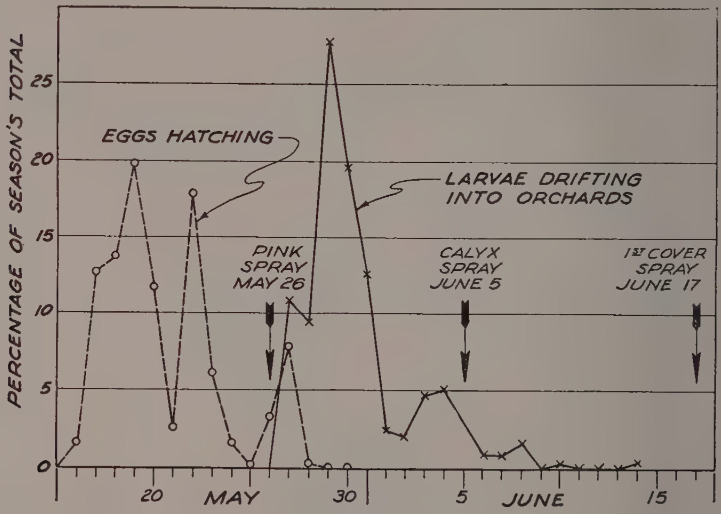

FIG. 13. Activity of Gypsy Moth at Highmoor Farm during the spring of 1940.

CONTROL OF GYPSY MOTH

When the problem became acute during the outbreak in 1935 and 1936, the control of the gypsy moth in apple orchards was not well understood, and Maine apple growers suffered considerable losses. As the principles of control became clearer, the growers were able to prevent any material loss, and now gypsy moth control has become largely routine practice in most Maine orchards.

In a well-sprayed orchard few, if any, gypsy caterpillars should reach full growth. The full-grown larvae can crawl short distances, and there is a slight chance that a few caterpillars may crawl onto the outside rows of apple trees from adjoining woods. The female moths cannot fly into the orchard from outside areas of infestation. Therefore, practically no gypsy moth eggs can be deposited within the well-sprayed orchard.

The important source of infestation, in the well-sprayed orchard, is invasion by the young air-borne larvae that drift into the orchard during the period of apple bloom.

Experiments showed that lead arsenate (3 pounds per 100 gallons of standard spray) thoroughly applied in the "pink," the petal fall, and

the first cover periods, killed the young larvae, and gave practically complete control of the gypsy moth. Liquid spray was somewhat more effective than dust. Where lead arsenate dust is used for gypsy moth, it usually is advisable to apply either 15 per cent or 25 per cent lead arsenate.

DDT has proved especially effective against gypsy moth. Probably DDT, as applied for oystershell scale control, will also control gypsy moth in the apple orchard.

GREEN APPLE APHID[14]

The green apple aphid is the aphid most generally injurious to apples in Maine. Some seasons have been especially favorable for the green aphids, and many orchards have been generally infested. In other years, conditions appeared to be less favorable, and infestation generally was very light. There seems to be no regular periodicity in the occurrence of heavy or light green apple aphid infestation.

Injury. The green apple aphid usually attacks the most rapidly growing and most succulent shoots and terminal growths of the apple trees. Young, vigorously growing trees especially are subject to attack. The aphids cluster on the upright stems and on the undersides of the leaves. The leaves on the infested terminals become cupped and rolled. Extreme infestation may cause yellowing and dropping of many of the leaves, and there may be some injury to the main stems of the infested shoots. Generally the injury to the tree as a whole is not of great importance.

When the fruit clusters become infested, the affected apples may be stunted and deformed. In Maine the green apple aphids do not frequently infest the fruit clusters severely enough to cause much loss.

The greatest damage from green apple aphids in the bearing orchard is caused by the blackening of the fruit by a sooty fungus which grows on the honeydew produced by the aphids. The aphids constantly excrete droplets of liquid honeydew, which rain downward through the tree. The honeydew collects on leaves, branches, and fruits. Thus, even apples that are not directly infested with the aphids may become coated with honeydew, and blackened by the resulting sooty fungus. Frequent showers may wash off most of the honeydew, and reduce fruit injury. In dry seasons the honeydew accumulates, and the blackening of the fruit is more likely to be severe.

Life Stages and Seasonal Cycles. The winter eggs are small (approximately 1/50 inch long), bright green when first deposited, but soon become glistening black. The eggs are placed on the surface of the bark of infested shoots.

The eggs hatch rather late in the delayed-dormant period. The newly-hatched aphids are very small and dark green. They feed upon the developing apple buds by sucking the sap from the green tissues. All of the aphids that hatch from the eggs develop into wingless females known as "stem mothers."

Most of the stem mothers and the aphids of all the summer generations that follow are bright green, but some of the aphids are of various

[14] *Aphis pomi* DeGeer.

shades to lemon yellow. The long "honey tubes" (cornicles) are black. The bright green to yellow bodies, with the long, black cornicles, distinguish the green apple aphid from all other aphids that infest apple trees.

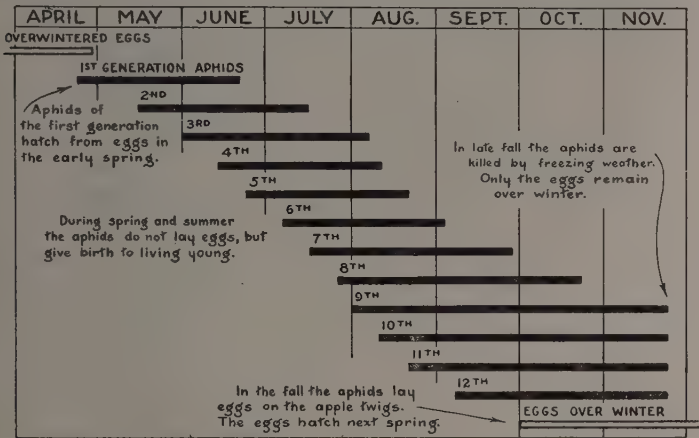

FIG. 14. Seasonal Cycles of the Green Apple Aphid at Highmoor Farm in 1938. During the summer months several generations of the aphids were present on the trees all the time. For example on August 1, seven generations were represented.

Throughout the summer the green apple aphids continue to live on apple trees[15] (see fig. 14). The aphids are all females, which multiply by giving birth to living young. As many as 12 generations have been observed during the season in Maine (Lathrop 1939). In each generation following the stem mothers, some of the aphids develop wings, and serve to spread the infestation throughout the orchard.

As long as the apples make rapid growth, and the tissues remain succulent, the green apple aphids flourish and the infestation builds up. During late summer, when the tree growth is reduced and the leaves become hardened, the rate of reproduction of the aphids decreases. Many natural enemies attack during this period, and the aphid populations are likely to decline.

In the fall, wingless males and egg-laying females are produced on the apple trees. Freezing weather kills the aphids, and only the eggs remain through the winter.

[15] Patch (1923) listed many other species of plants, in addition to apple, belonging to 24 botanic families, that she observed to be infested by *Aphis pomi* during the summer months. Aphid infestation on the plants listed has not been shown to be of great importance to the apple grower.

It is known that the behavior of the green apple aphid varies in the different apple-growing sections of this country (Lathrop 1921, Cutright 1930). Some of the variations in behavior are of considerable importence. For example, in most sections the green apple aphids lay eggs profusely in the early fall, usually beginning about September 1. By the time winter weather comes, the bark of the infested shoots usually is well covered with countless glistening, black aphid eggs. At hatching time in the spring, numerous centers of infestation develop immediately. The green apple aphids may infest a large proportion of the growing tips on many trees, and the blossom clusters frequently become infested.

In Maine the situation is somewhat different. The green apple aphids are slow in starting to lay eggs in the fall, and generally it is past the middle of September before noticeable numbers of eggs can be found. The eggs are produced only in comparatively small numbers. Usually the infested apple shoots have only a light scattering of eggs. In Maine, most of the eggs deposited by the green apple aphid are killed by severe weather during the winter. In the spring, it usually is difficult to find a colony of the green apple aphids, even in orchards that were severely infested during the preceding summer. Generally it is not until after the production of many winged aphids, along in June, that numerous colonies of the green apple aphid begin to be noticeable.

CONTROL OF GREEN APPLE APHID

In sections where a great many eggs survive the winter and heavy infestation of the green aphid is present early in the spring, it is advisable to apply a spray in either the dormant or the delayed-dormant period to destroy either the aphid eggs or the newly hatched aphids. In Maine the number of green apple aphid colonies in the early spring usually is so small, especially on bearing trees, that dormant or delayed-dormant applications often have not been worth the cost of treatment.

Maine growers usually delay treatment until after an infestation has become severe, in July or August. By that time the aphids are so well protected by the rolled leaves that it is difficult for any spray to contact and kill all of them. Such delayed treatments have not been completely satisfactory. Under favorable conditions, however, a spray applied even to severely infested trees can reduce the aphid population sufficiently to avoid material loss from the blackening of the apples.

To hold the green apple aphid infestation to a minimum, a spray should be applied as soon as winged forms have spread the aphid colonies through the orchard, and before the infested leaves have become rolled. Under favorable conditions a spray at this time may hold down infestation sufficiently, without further treatment, to suffice through the

rest of the season. Watch should be kept, however. It may be advisable to repeat the spray if the aphids begin building up again.

Spray tests have shown that nicotine sulphate (Black Leaf 40), 1 pound per 100 gallons of standard liquid spray, is effective for killing the aphids. The nicotine should be combined with wettable sulphur or lead arsenate plus enough lime (2 or 3 pounds) to activate the nicotine. Soap may be used as a spreader and activator, if the nicotine is not combined with some other material. Nicotine is most effective when applied while the air is calm and warm. There is little or no danger of injury to the apple tissues from the use of nicotine, and it is less destructive to beneficial insects than are most of the other contact insecticides.

In experimental tests TEPP has proved to be extremely toxic to aphids, and it seems to be somewhat more effective than nicotine against the aphids protected by the rolled leaves. Unfortunately TEPP is more likely to injure the apple tissues, and it is more destructive to beneficial insects than is nicotine.

ROSY APPLE APHID[16]

In midsummer or later, occasional clusters of severely stunted and badly puckered apples may be found in Maine apple orchards. The injury is caused by the early infestation of blossom clusters and of the young apples by the rosy apple aphid. The loss caused by this pest in Maine seldom is sufficient to warrant the application of a spray for its control.

Life Stages and Seasonal Cycles. The winter eggs of the rosy apple aphid are tucked away in cracks and creases in the bark of the fruit spurs or on the branches, rather than on the growing shoots. Otherwise, the eggs are indistinguishable from those of the green apple aphid.

The rosy apple aphid eggs hatch a few days earlier than the eggs of the green apple aphid. The "stem mothers" and the later generations of the rosy apple aphid vary from a rosy-pink to deep bluish or purplish color.

The rosy apple aphids are especially likely to infest the fruit clusters. After several generations on apple, the aphids develop wings. They leave the apple trees, and fly to the narrow-leaf plantain,[17] where this species spends the summer. In the fall, beginning about apple-picking time, winged migrants fly from the plantain and return to the apple. Here the wingless, egg-laying females are produced on the undersides of the mature apple leaves. Soon a flight of winged male aphids migrates from plantain to the apple trees. The male and female aphids mate, and the winter eggs are produced.

CONTROL OF ROSY APPLE APHID

The rosy apple aphid can be controlled by the application of dormant dinitro spray to destroy the eggs, or by a contact spray such as TEPP or nicotine sulphate, used after the eggs have hatched, to destroy the young aphids. Control measures seldom have been necessary in Maine apple orchards.

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16 *Anuraphis roseus* Baker.

17 *Plantago lanceolata* L.

APPLE-GRAIN APHID[18]

In the early spring, the apple-grain aphid usually is the most common and generally distributed aphid on apple trees in Maine. This aphid generally is much less abundant in Maine apple orchards than it is in the orchards to the south and west; for example, in Massachusetts, Connecticut, and New York.

Injury. The apple-grain aphid, like the rosy apple aphid, is especially likely to attack the apple blossom clusters. On the most heavily infested fruit clusters, the leaves may be somewhat cupped, and some of the apples may be slightly injured. The injury usually has been so slight that Maine apple growers have suffered no appreciable loss as a result of an apple-grain aphid infestation.

Life Stages and Seasonal Cycles. The eggs of the apple-grain aphid, like those of the rosy apple aphid, are hidden in irregularities of the bark of fruit spurs and similar places on the apple trees.

The eggs of the apple-grain aphid are the first of the aphid eggs to hatch on apple trees in the spring. The newly hatched aphids can be found on the apple buds about as soon as the bud tips show green.

The "stem mothers" and the individual aphids of the later generations are pale green, with a broad band of slightly darker green extending the full length of the body. The "honey tubes," or cornicles, of the apple-grain aphid are very short and are not deeply colored.

By the time the apples are in full bloom, the apple-grain aphids usually have reached maximum abundance. The aphids soon take wing, leaving the apple trees and flying to various species of grains and grasses. Here several generations are produced during the summer. In the fall, return migrants fly to the apple trees where the winter eggs are deposited.

Control of Apple-Grain Aphid. Because the apple-grain aphid causes so little damage in the apple trees, control measures have not been necessary in Maine orchards. Many apple growers in southern Maine were deeply concerned by an exceptionally heavy and widespread infestation of apple-grain aphids in the spring of 1939. Some of the growers sprayed their trees to destroy the aphids. Whether the trees were sprayed or not, however, no material injury resulted from this aphid infestation.

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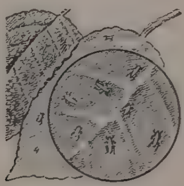
[18] *Rhopalosiphum prunifoliae* (Fitch). = R. fitchii (Sand.).

WHITE APPLE LEAFHOPPER[19]

In a general way, the white apple leafhopper ranks as a minor pest in Maine apple orchards. When an outbreak occurs, however, it causes the apple grower such concern that it assumes almost primary importance.

When an outbreak of white apple leafhopper occurs, the leafhoppers usually increase in numbers in the orchard for a period of two or three years before reaching their greatest abundance. Then the hoppers usually decrease rapidly for a year or two, probably as a result of the increasing effectiveness of natural enemies. After the outbreak has subsided, the orchard may be comparatively free from leafhoppers for a considerable period of years before another outbreak occurs. Outbreaks are likely to occur in different orchards every year.

Injury. The white apple leafhopper feeds upon the underside of the mature apple leaves, and it is most likely to attack mature trees. The leafhoppers feed by piercing the leaves from the underside, and sucking out the leaf contents. Each feeding puncture produces a very small white spot upon the upperside of the leaf (see fig. 15). The white spots become noticeable first along the midrib and the main vein branches of the leaf. Later, the entire surface of heavily infested leaves may become severely bleached and colorless.



LEAFHOPPER

FIG. 15. White Apple Leafhopper. The leaf in the background shows the white spotting on the upper side, caused by leafhopper feeding. The magnified section shows the leafhoppers on the underside of the leaf.

The leafhoppers excrete droplets of a dark-colored liquid, which fall upon the leaves and fruit. Rain usually washes the leafhopper stain from the fruit before picking time. In dry seasons, however, the stain may accumulate until the fruit becomes badly discolored.

When the leafhoppers become abundant, the swarms of flying adults in the trees are exceedingly annoying to the apple pickers.

[19] *Typhlocyba pomaria* McAtee.

Life Stages. The *adult* of the white apple leafhopper is white and often tinged with pale yellow. It is small and slender, between 1/8 and 3/16 inch long, with wings folded over the back when at rest, and legs that give the insect much the appearance of an exceedingly small grasshopper. The adults crawl and fly very actively. The *egg* is inserted into the tissues of an apple leaf or stem. The egg can be found only by careful examination under a lens or a microscope. The *nymph,* that hatches from the egg, resembles the adult leafhopper, except that it has no wings. The nymphs crawl actively but cannot fly. The full grown nymph develops wings, and becomes a new adult leafhopper.

SEASONAL CYCLES

The winter is spent in the egg stage. The winter eggs are inserted just under the outer bark, mostly on one- or two-year-old wood growth. Most of the overwintered eggs hatch before the apples are in bloom, usually during the last week or 10 days in May (see fig. 16). The leafhopper nymphs feed and grow on the undersides of the leaves. Considerable numbers of nymphs begin transforming to the adult stage toward the end of the second week in June, about 12 days after petal fall. Before the end of June, 24 days after petal fall, practically all of the nymphs have matured into the summer brood of adult leafhoppers, and by this time the older leaves may show considerable whitening from the leafhopper feeding.

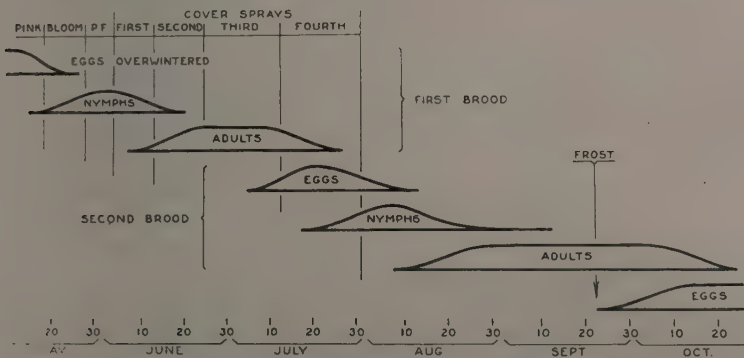


FIG. 16. Seasonal Cycles of the White Apple Leafhopper. DDT is effective against the nymphs of the first brood, when applied either in the pink spray or at petal fall.

The adult leafhoppers of the summer brood lay their eggs in the leaf stems or in the midrib or larger veins of the leaves. The leafhoppers

of the first or summer brood, may continue to live and lay eggs through the month of July and during early August.

The nymphs of the second brood begin hatching the third week in July, 50-55 days after petal fall, and the newly hatched nymphs continue to appear until about the third week in August, 80-85 days after petal fall.

Adults of the second, or fall brood, begin to appear shortly before mid-August, 72 days after petal fall. During the last half of August, the number of adults increases, as the nymphs decrease, and by mid-September, 110 days after petal fall, nearly all of the leafhoppers are in the adult stage. As soon as frosty nights occur, the adult hoppers begin laying the winter eggs under the bark, mostly of the last two years' growth. The hoppers are present and continue to lay eggs through most of October.

CONTROL OF WHITE APPLE LEAFHOPPER

Tests in orchards at Monmouth show that DDT in the petal-fall application, while the leafhoppers are in the wingless nymph stage, gives effective control. By destroying the nymphs of the first generation, further development of the leafhoppers is prevented, and control is effective through the season. Nicotine sulphate (Black Leaf 40) may be used instead of DDT, but nicotine is likely to be less effective than DDT.

DDT applied at petal fall, for the control of leafhoppers, also is useful in combating oystershell scale.

Applications against the second brood have been much less effective than treatments against the first brood.

It is interesting to note that in the summer of 1953, the leafhoppers were much more numerous on trees sprayed with glyodin after petal fall, than on trees treated with sulphur through the season.

POTATO LEAFHOPPER[20]

The potato leafhopper is known to attack apples occasionally in Maine. It also attacks and may cause severe injury to potatoes, beans, and many other plants. Outbreaks of the pest on apples occurred in 1941 and '42. Since that time it has not been an important pest on apples in this state.

Injury. The potato leafhopper attacks the rapidly growing terminal growth, and is most likely to infest young, vigorously growing trees. One or two-year old trees in the nursery are especially likely to be injured. The infested leaves become rolled or cupped, and the terminal growth may be severely stunted. The axillary buds, that should remain inactive through the season, frequently are stimulated to immediate growth, which gives the severely infested young tree a "witches' broom" appearance. In addition to the direct injury to the apple tissues, the potato leafhopper may transmit fire blight and possibly other apple diseases (Lathrop 1918).

Life Stages. The life stages of the potato leafhopper are similar to those of the white apple leafhopper, except that the adults and the nymphs of the potato leafhopper are green in color.

SEASONAL CYCLES

The potato leafhopper winters over in the far south, where it probably remains active through the winter. With the approach of spring, the adults fly northward and infest food plants in new localities as the growing season advances (Poos, 1932).

In 1941 and '42, young apple trees in a nursery at Monmouth were found to be severely infested by the middle of July. Probably there are two generations of leafhoppers during the season, but the broods are not clearly defined. The summer eggs are laid in the apple leaf stems or the main veins. No winter eggs have been found in Maine, and the species dies out with the approach of cold weather in the fall.

CONTROL OF POTATO LEAFHOPPER

In 1941 and '42 it was found that the potato leafhoppers on apple trees could be killed by the application of nicotine sulphate. However, a single application was not sufficient to give complete protection from severe infestation. In more recent years, DDT has proved to be very effective against leafhoppers.

Growers should keep watch of young apple trees for potato leafhoppers, beginning about mid-June. DDT should be applied as soon as the adult hoppers appear, and if necessary the treatment should be repeated in about 10 days.

[20] *Empoasca fabae* (Harris).

OYSTERSHELL SCALE[21]

The oystershell scale has long been known as a pest of apple trees in Maine. During the past 15 years the injury from this pest has increased greatly in Maine orchards. The increased severity of infestation has followed the increased number of applications, and the more thorough applications of sulphur fungicides for the control of apple scab. The sulphur fungicides have little direct effect upon the oystershell scale, but apparently the sulphur destroys many of the beneficial insects that help to keep the scale under control. Severe scale infestation has been observed repeatedly on trees sprayed with a full schedule of sulphur fungicides, while adjacent unsprayed check trees remained practically free from the scale.

Injury. The bark on any part of an infested tree may become covered with the scales (see fig. 17). The living, growing insect beneath

FIG. 17. Apple Twig Severely Infested with Oystershell Scale. Notice the scales on the twig and fruit, and the stunted growth of the twig.

[21] *Lepidosaphes ulmi* (L.).

the scale cover sucks the sap from the tree, and causes the injury. Severely infested trees soon become weakened. The foliage becomes sparse, and the bloom becomes light. Many of the leaves and partly-grown apples may drop from severely weakened trees in late summer. The most severely injured branches and limbs may be killed. The scales often occur on the fruit, but usually the presence of the scales on the harvested apples is of minor importance.

Two kinds of oystershell scale are known. One kind attacks apples and other fruit trees. The other attacks a number of woodland trees and ornamental shrubs, but has not been known to attack apples or other fruit trees (Griswold 1925).

Life Stages and Seasonal Cycles. The winter is spent in the egg stage under the scale covers on the apple bark. The individual egg is very small, and nearly white in color. In western New York, Griswold found from 41 to 105 eggs under each scale cover, with an average of 73 eggs per scale. Scales from apple trees at Highmoor Farm contained from 11 to 67 eggs, with an average of 44 eggs under each scale.

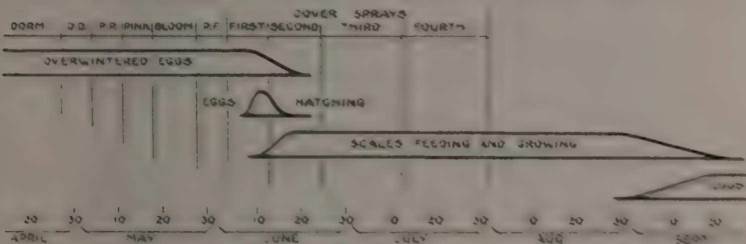


Fig. 18. Seasonal Cycles of the Oystershell Scale. The dates and spray periods are average for Highmoor Farm. DDT applied in the petal-fall spray and again when the eggs begin to hatch, is effective against the newly hatched crawlers.

Hatching of the Eggs. Observations at Highmoor Farm and in other orchards at Monmouth, showed that the eggs begin to hatch in 4 to 10 days after McIntosh petal fall, and practically all of the eggs hatch within a period of 10 to 15 days (see fig. 18).

The "Crawler." The first stage larva, or "crawler," that hatches from the egg is an exceedingly small insect. To the unaided eye it appears as a white speck of pin-point size on the apple bark. Under the microscope, the "crawler" is seen to have an oblong, flattened body, with six legs and a pair of "feelers." In spite of their extremely small size, the "crawlers" often are produced in such countless numbers that the surface of the apple bark, on severely infested branches, appears whitened by the young crawling scales.

Formation of the Scale Cover. Usually within 24 to 48 hours after the "crawler" hatches, it settles down, inserts its sucking tube into the bark, and begins the formation of the scale cover. The settled insect soon sheds its skin, and loses its legs and feelers.

Through the summer, the almost shapeless scale insect feeds and grows. As the insect grows it enlarges the scale cover, which gives practically perfect protection against any insecticide that can be applied. The full-grown scale cover is shaped like a miniature oyster shell, about ⅛ inch long and about one-quarter as wide. The color is almost exactly the same as the apple bark. The body of the female insect fills the space under the scale cover. All of the oystershell scales that have been observed in Maine have been females, and it is doubtful if males of this species ever occur (Griswold 1925).

Egg Laying. Toward the end of August or early in September, the scales begin laying eggs under the scale covers. As the eggs are produced, the body of the female grows smaller, and is pushed toward the end of the scale cover. By the time frosty weather comes, the scale cover is filled with eggs, and the insect dies. The eggs remain through the winter, to hatch next spring. After the eggs have hatched, the old, empty scale covers remain in place on the apple bark. Some of the old scale covers may remain on the trees for two or three years, or longer, before they finally weather off.

CONTROL OF OYSTERSHELL SCALE

When the oystershell scale problem became acute in 1940, experiments were undertaken to discover an effective method of control. Spraying in the late fall or early spring with winter strength of liquid lime-sulphur or with oil proved to be of no practical value.

Nicotine sulphate (Black Leaf 40), applied as the young scales were hatching, also failed to give control.

The dinitro sprays, Elgetol and Dinitro Dry, applied to the dormant trees late in the fall or early in the spring, gave a considerable degree of control (Lathrop 1946). In spite of persistent spraying with dinitro, however, the apple growers were losing the battle against oystershell scale, until DDT became available.

DDT for Oystershell Control. Experiments at Highmoor Farm in 1946 showed that DDT is effective for killing the newly-hatched scale crawlers. Two applications of DDT, either liquid (3 pounds of 50 per cent wettable powder in 100 gallons of standard spray) or dust (5 per cent DDT) gave thoroughly effective control (Lathrop 1947). DDT is effective when applied first in the petal-fall period, and a second time 7 to 10 days after the first application.

FIG. 19. A.–McIntosh apple tree severely infested with oystershell scale. Notice the sparsity of the foliage and the weakened branches. B.–A similar tree after one season of treatment with DDT. Notice the better foliage and more vigorous appearance of the tree. C.–Another tree after two seasons of treatments with DDT. Notice that the tree is returning to a normal state of health.

Trees that have been severely injured by oystershell scale make astonishingly rapid recovery after the scales have been killed off with DDT (see fig. 19). After two or three years of scale control, the trees return to vigorous health.

DDT appears to have answered the oystershell scale problem for Maine apple growers.

ROUNDHEADED APPLE-TREE BORER[22]

The roundheaded borer is a persistent pest in Maine apple orchards and is especially injurious to young trees. Constant attention is required in the young orchard to protect the trees from severe injury or destruction.

Injury. The first indication of severe borer injury usually is the presence of sawdust-like material, or frass on or about the base of the infested tree.

Injury to the tree is caused by the borer grubs, which feed upon the inner bark and the sapwood. The older borers frequently penetrate

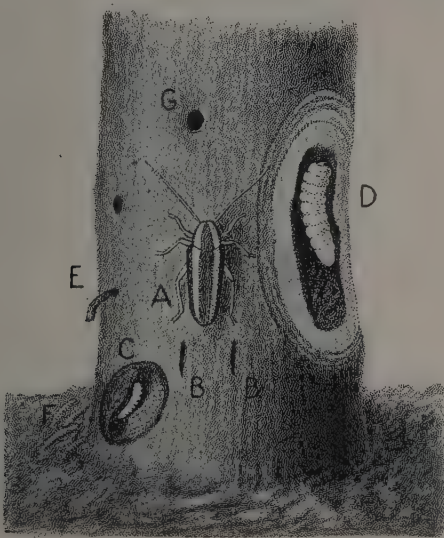


Fig. 20. Life Stages of Roundheaded Apple-Tree Borer in a Young Apple Tree. A.–The adult female beetle. B.–Slits in the bark in which the beetle laid her eggs. C.–A young borer working in the bark during the first summer of its life in the tree. The grower should learn to find the young borers, and remove them before material injury has been done to the tree. D.–An older borer in a tunnel deep in the wood of the tree. E.–Sawdust-like frass being pushed out from a borer tunnel. F.–Sawdust-like castings collect about the base of the tree. G.–Exit hole from which an adult beetle emerged.

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[22] *Saperda candida* Fabricius.

deeper into the tree, and some of the tunnels extend through the heartwood (see fig. 20). Borer-infested trees may be partly or completely girdled, and severely weakened.

The tunnels in the tree usually extend from two or three inches below the soil surface, upward to 12 or 14 inches above ground. Occasionally the borers may occur higher in the tree, and according to Brooks (1920), they may go down into the root to a distance of a foot or more. Young apple trees frequently break off where the trunk has been tunneled and weakened by the borers (see fig. 21).

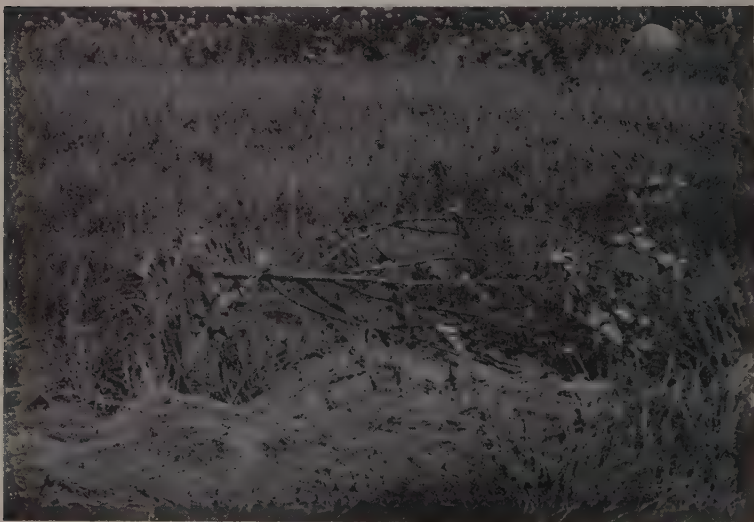

FIG. 21. Damage Due to Roundheaded Apple-Tree Borer. A young apple tree broken off where it was girdled by borers at the top of a mouse protector screen.

The adult beetles feed upon the bark of the smaller branches, and upon the leaves. King (1920) reported the beetles feeding upon the apples. Feeding by the beetles seldom causes material injury to the tree.

Life Stages. The *adult* is a "long-horned" beetle, cinnamon brown in color, with a conspicuous nearly-white stripe on each side of the back, extending the entire length of the insect. The undersides of the body, as well as the legs and antennae, are light or nearly white in color. The male beetle is about ⅝ inch, and the female about ¾ inch in body length. The "horns" (antennae) are slightly longer than the body of the male, and are slightly shorter than the body of the female. The adults are

moderately active, crawling and flying, or dropping from the tree to escape when disturbed.

The *egg* is inserted into the bark by the female beetle. It is about 1/8 inch long, narrow in shape, light cream-colored when first deposited, and gradually darkening to brownish.

The *larva* hatches from the egg. It is a legless grub-like borer, very light colored, with somewhat darker head, and with strong jaws. The full grown borer attains a length of 1½ to 1¾ inches.

The *pupa,* or resting stage, develops from the full-grown larva within the borer tunnel, near the outer surface of the bark. The structures of the developing adult can be seen folded against the body of the pupa. The pupa transforms into the adult beetle, which gnaws a hole out through the bark and emerges from the tree.

SEASONAL CYCLES

The roundheaded apple-tree borer spends the winter in the larval stage in the tunnels within the tree.

During the spring and summer, the full-grown larvae transform to pupae. The pupal stage may last as long as 2 or 3 weeks before the adult beetle emerges.

Emergence of Adults. The adult beetles were observed to begin emerging on the average about 10 days after McIntosh petal fall, or during the second week in June at Highmoor Farm (Lathrop 1942). The peak of emergence occurs about 25 days after petal fall, and the beetles continue to emerge, in decreasing numbers, through the rest of the season (see fig. 22).

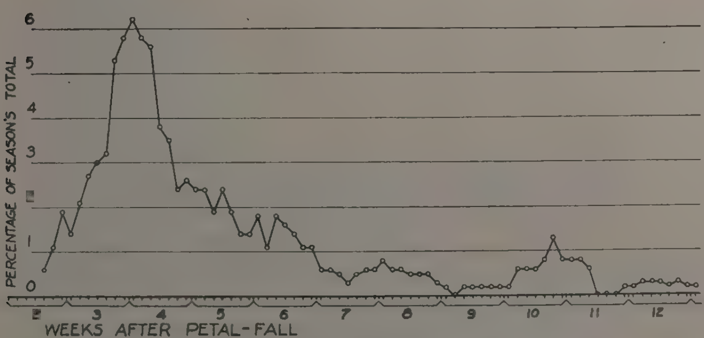

FIG. 22. Emergence of Adult Roundheaded Apple-Tree Borer Beetles at Monmouth, Maine. Average for 1938 to 1941, inclusive.

Records of 25 female beetles emerging on various dates through the season at Highmoor Farm and kept in cages on young apple trees, showed the average life to be about 32 days, with a range from 4 to 68 days. On the average the life of the male was somewhat shorter than that of the female. These observations are in line with corresponding data from Brooks (1920) and Hess (1940).

Egg laying begins about 20 days after petal fall, and continues through July and August. The period of maximum egg production probably extends from 40 to 55 days after petal fall, or during the two weeks of mid-July at Highmoor Farm.

When preparing to lay an egg, the female beetle gnaws a narrow, nearly vertical slit in the bark. The slit usually is from ¼ to ½ inch long. The beetle then neatly deposits an egg through the slit and into the bark. Sometimes more than one egg may be deposited in the slit. In young trees, the eggs usually are inserted under the bark, but in old trees the eggs more often are placed in the bark.

Normally, most of the eggs are placed near the soil surface. Sometimes they are placed higher in the tree, and the beetles readily lay eggs at the tops of the wire screens usually placed about young apple trees, for protection against mice.

Borer Activity. When the young borer hatches from the egg, it begins feeding and boring into the bark. As the borer grows, a tunnel is formed. Sawdust-like wood fragments are thrown out from the tunnel, and may collect about the base of the tree. Strings of brown castings frequently exude from the borer tunnels.

During the first summer, the borers usually confine their activities to the bark of the tree. During the second summer, the large borers go deeper into the wood. During the third or the fourth summer, the borers complete their development, enter the pupal stage, and then transform into adult beetles. Brooks (1920) states that his records obtained at Winthrop, Maine, show that "of 24 individuals, none matured in 2 years, 6 issued as beetles in 3 years from the egg, and 18 required 4 years to develop from eggs to adults."

CONTROL OF ROUNDHEADED BORER

The borers are likely to be most injurious to trees planted near woods or brushy places. Trees in such places should be given special attention. It might be helpful to destroy any hawthorn (*Crataegus* spp.) bushes, shadbush, or sugar plum (*Amelanchier* spp.) and mountain ash (*Pyrus* spp., *Sorbus* spp.) that can be found in or near the orchard. Such bushes may serve as centers of borer infestation.

A number of control methods have been tested experimentally by various workers and have been tried with more or less success by apple growers. Hess (1940) gives an excellent summary. None of the control practices reported so far has proved sufficiently effective to eliminate the necessity for careful inspection and worming of young trees twice each year.

Worming. Young trees should be inspected each year in the fall and again in the spring.

The most practical time for the fall inspection is soon after the apples have been picked. Practically all of the borer eggs will have hatched by that time, and the young borer larvae will still be feeding in the bark.

The spring inspection will be effective at any time before the borer beetles begin laying eggs in the trees—2 or 3 weeks after petal fall.

To make the inspection, the wire screen mouse-guard should be removed, and the base of the trunk exposed for several inches below the soil level. The members of the worming crew should learn to recognize the slits in the bark where the eggs were deposited and also the early symptoms that mark the presence of the small, young borers.

In the fall, most of the borers will be small and usually working reasonably near the surface of the bark. Even in the spring many of the borers will be in or just under the bark.

The importance of finding and destroying the young larvae, with a minimum of cutting, and before the borers have done much injury to the trees, cannot be too strongly emphasized.

The young borers usually can be exposed and destroyed by only slight cutting with a sharp knife or with a sharp, narrow gouge (rounded chisel).

The gouge is especially useful in exposing the deeper tunnels of the older borers. At all times, an effort should be made to avoid unnecessary cutting. After the tunnel has been exposed, the borer can be destroyed by means of a flexible wire pushed into the tunnel. When the borer cannot be reached with the wire, a small wad of cotton batting moistened with a few drops of carbon disulphide, pushed deep into the burrow, will kill the borer. Too much carbon disulphide may injure the tree.

Protectors. Various paints and washes have been tried for preventing the borer beetles from laying eggs in the tree trunks. No paint or wash seems very effective, however, and it is doubtful if any such treatment is worth the cost of application.

Many growers close the tops of the wire screen mouse-guards with a wad of grass. This forces the beetles to lay the eggs above the top of the mouse-guards. Numerous trees have been observed to be severely

injured above the guard, and some of the infested trees break off at this point. If the wire screen is fine enough (6 or 8 mesh per inch), and the top is fitted with a tight plug of burlap or of cotton batting, many of the borer beetles will be trapped when they emerge within the guard, and may die without laying eggs.

Spraying for Borer Control. The adult borer beetles feed rather freely upon the bark of the apple terminals and to some extent upon the leaves and fruit. Lead arsenate applied to the trees kills many of the beetles. To be most effective against the borers, three applications should be made to the young orchard. The first application should be made about two weeks after petal fall, and the other sprays should follow at intervals of about two weeks.

APPLE MEALYBUG[23]

The apple mealybug is a European insect that was accidentally introduced into Maine and has spread into Nova Scotia and British Columbia (Rau 1942). In Maine, the mealybug ordinarily is a pest of little importance, with light infestations only in an occasional orchard. In 1941, however, a severe and widespread outbreak occurred in Maine orchards. The outbreak reached a peak in 1942, when heavy infestation was reported in the towns of Alna, Ellsworth, Embden, Enfield, Hampden, Hope, Jefferson, Monson, Skowhegan, and Vassalboro. The outbreak declined in 1943, and by 1944 the pest had returned to its normal status.

Injury. The mealybug is a sucking insect, and severe infestation may cause considerable injury to the leaves. The greatest damage, however, was caused by a sooty fungus that developed on the honeydew excreted by the bugs. Severely infested trees became blackened, and the apples were ruined by the sooty discoloration. No practical method was found for removing the dirty, black deposit from the fruit, and in several severely infested orchards, the crop was practically a total loss.

Plants Attacked. Apparently all varieties of apples are attacked by the apple mealybug, as well as other kinds of fruit trees, shade trees and forest trees. Recently the pest has been reported on potatoes in Aroostook County (Simpson and Shands, 1950), adjacent to or downwind from neglected apple plantings.

Life Stages. The full grown *female* mealybug is a fat, soft bodied, pale yellowish insect, about 1/10 inch long, and about two-thirds as wide as long. It has six small legs on the underside, and is covered with a fluffy mass of white, woolly material on its upperside.

The *male* is a small delicate, two-winged, active insect.

The *eggs* are deposited by the female within the woolly fluff with which she is covered. There may be a hundred or more eggs in the mass. When the eggs are dug out of the wool, they appear as a mass of very small, bright-yellow granules.

The *nymph* or "crawler" that hatches from the egg is a flattened, oval, six-legged insect, so small that it is not readily seen without the use of a magnifying lens. The nymphs feed and grow, mostly on the undersides of the leaves. After shedding its skin several times, the nymph becomes full grown and transforms into the adult male or female.

SEASONAL CYCLES

The apple mealybug hibernates over winter as partly-grown individuals in small, white, waxy cocoons, mostly on the trunks and large

[23] *Phenacoccus aceris* Signoret. Det. by George J. Rau.

limbs of the infested trees (Lathrop and Dirks 1944a). The hibernating mealybugs gather in protected places such as old pruning wounds and under flakes of loose bark on the trunks and larger branches. On severely infested trees at the height of an outbreak, the trunks and large limbs may be so covered with the white cocoons that the bark appears as though whitewashed.

The partly-grown mealybugs emerge from hibernation during the delayed dormant period, and crawl sluggishly all over the trees. The

FIG. 23. Tree Infested with Apple Mealybug.

bugs feed by sucking the juice from the green stems and leaves. About the time of petal fall, the full grown mealybugs begin to gather on the woody parts of the trees, where they settle down and soon produce a fluffy, white, woolly covering (see fig. 23). After mating with the winged males, the females begin producing eggs under the woolly covering. Egg production continues for 30 or 40 days.

The eggs begin to hatch about 25 days after petal fall, or usually during the last week in June. Hatching continues for 30 or 40 days. By the third week in July, 55 days after petal fall, most of the eggs have hatched.

The newly hatched mealybugs crawl to the undersides of the leaves where they feed and grow. Here they excrete considerable quantities of honeydew which rains down in the form of minute droplets from the infested leaves. By the end of July or early in August the accumulation of honeydew becomes noticeable on the infested trees and on the grass under the trees.

Late in August and early in September, the partly-grown mealybugs stop feeding and crawl to the trunks and branches of the trees where they prepare for hibernation.

During September the accumulated honeydew becomes infected by the sooty fungus that blackens all parts of the trees, including the fruit.

CONTROL OF APPLE MEALYBUG

Marshall (1942) in British Columbia recommended oil spray during the dormant or the delayed dormant period. He found that oil having a viscosity of 108 seconds Saybolt at 100° F., was more effective than oil of either higher or lower viscosity. Tests in Maine showed that dinitro (Elgetol or Dinitro Dry) applied as a dormant spray in the early spring gave considerable control.

Nicotine sulphate (Black Leaf 40) applied either in the petal fall spray, or later against the newly hatched crawlers, was not effective.

In limited tests, DDT (3 pounds of 50% wettable powder in 100 gallons) applied against the newly hatched crawlers late in June, appeared to give satisfactory control.

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TABLE 1

APPLE FRUIT FLY

Emergence of Adult Flies at Highmoor Farm
Summary of Emergence During 22 Years

	Earliest, latest, and average time when specified percentages of flies had emerged													
	0.1 Per cent		10 Per cent		25 Per cent		50 Per cent		75 Per cent		90 Per cent		99 Per cent	
	Date	Days[1]	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days
rliest[2]	June 18	25	June 29	34	July 4	39	July 9	46	July 15	53	July 21	57	Aug. 2	66
test[2]	July 12	42	July 20	52	July 24	56	July 29	60	Aug. 2	66	Aug. 8	73	Aug. 27	91
verage	June 30	33	July 10	43	July 14	47	July 19	52	July 25	58	July 30	63	Aug. 13	77

The column headed "Days" shows the number of days after McIntosh petal fall on which the specified ercentage of flies had emerged.

The earliest (or the latest) time as shown by calendar date and by days after petal fall did not necessarily ccur in the same year.

TABLE 2

APPLE FRUIT FLY

Summary of Emergence By 10-Day Periods
Highmoor Farm, 1950

Period	Dates (Inclusive)		Flies emerged, by periods (per cent)		Sex of flies emerged during each period (per cent)		Female flies emerged by periods (per cent)	
	From	To	During each period	To end of each period	Female	Male	During each period	To end of each period
1st	July 2	July 11	8.4	8.4	71.0	29.0	11.0	11.0
2nd	July 12	July 21	40.4	48.8	61.4	38.6	45.9	56.9
3rd	July 22	July 31	40.2	89.0	48.6	51.4	36.2	93.1
4th	Aug. 1	Aug. 10	9.0	98.0	34.2	65.8	5.7	98.8

TABLE 3

APPLE FRUIT FLY

Emergence of Flies at Highmoor Farm, 1950

	Time when specified percentages of flies had emerged													
	0.1 Per cent		10 Per cent		25 Per cent		50 Per cent		75 Per cent		90 Per cent		99 Per cent	
	Date	Days[1]	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days
year[2]	July 2	32	July 12	42	July 16	46	July 21	51	July 27	57	Aug. 1	62	Aug. 15	76
d year[2]	July 9	50	July 17	47	July 20	50	July 25	55	July 31	61	Aug. 5	66	Aug. 20	81
mbined	July 3	33	July 12	42	July 17	47	July 22	52	July 27	57	Aug. 2	63	Aug. 16	77
ale	July 3	33	July 13	43	July 18	48	July 23	53	July 29	59	Aug. 3	64	Aug. 21	82
male	July 2	32	July 11	41	July 15	45	July 20	50	July 25	55	July 30	60	Aug. 12	73
n	July 1	31	July 9	39	July 12	42	July 16	46	July 21	51	July 27	57	Aug. 10	71
rt Shade	July 8	38	July 17	47	July 19	49	July 24	54	July 29	59	Aug. 3	64	Aug. 21	82
ade	July 7	37	July 17	47	July 19	49	July 24	54	July 29	59	Aug. 2	63	Aug. 14	75

The column headed "Days" shows the number of days after McIntosh petal fall on which the specified ercentage of flies had emerged.

The terms "1st year" and "2nd year" refer to emergence of flies after one winter in the soil, and after two winters in the soil

TABLE 4

APPLE FRUIT FLY

Comparison of Emergence of Adult Flies at Four Localities, 1945

Locality	Date of petal fall	Time when specified percentages of flies had emerged													
		0.1 Per cent		10 Per cent		25 Per cent		50 Per cent		75 Per cent		90 Per cent		99 Per cent	
		Date	Days[1]	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days	Date	Days
Cumberland Center	May 22	June 29	39	July 8	48	July 14	54	July 17	57	July 21	61	July 26	66	Aug. 8	79
Monmouth	May 23	July 1	40	July 10	49	July 16	55	July 21	60	July 27	66	Aug. 3	73	Aug. 19	89
Orono	May 30	July 8	40	July 22	54	July 28	59	Aug. 4	67	Aug. 14	77	Aug. 22	85	Aug. 29	92
Patten	June 9	July 12	34	July 21	43	July 25	47	July 30	52	Aug. 6	59	Aug. 12	65	Aug. 21	74

[1] The column headed "Days" shows the number of days after McIntosh petal fall on which the specified percentage of flies had emerged.

TABLE 5

Quantities of Dust or Spray Applied for Apple Fruit-Fly Control

Date	Application: Method	Application: Machine	Quantity of dust or spray per tree unit[1]	Insecticide: Active ingredient	Insecticide: Concentration
1947					
July 9	Dust	Liqui-duster	1.92 pounds	Lead arsenate	25 per cent
16			1.60		25
22			2.03		15
			—	DDT	5
31			1.68	Lead arsenate	15
			—	DDT	5
1948					
July 13	Dust	Liqui-duster	1.86 pounds	Lead arsenate	15 per cent
20			1.89		15
29			1.65		15
1949					
July 1	Dust	Liqui-duster	2.06 pounds	Lead arsenate	15 per cent
14			1.91		15
20			2.93		15
29			1.58		15
1950					
June 29	Concentrate	Mist blower	.714 gallon	Lead arsenate	6 pounds: 30 gallons
July 7			.629		6 30
15			.650		6 30
Aug. 1			.778		6 30
1951					
July 2	Concentrate	Mist blower	.927 gallon	Lead arsenate	8 pounds: 30 gallons
10			1.119		8 30
24			1.012		8 30
30			.799		8 30
1952					
June 27	Concentrate	Mist blower	.906 gallon	Lead arsenate	6 pounds: 30 gallons
July 11			.959		6 30
24			1.172		6 30
1953					
July 7	Concentrate	Mist blower	2.291 gallons	Lead arsenate	6 pounds: 50 gallons
15			1.971		6 50
Aug. 6			2.770		6 50
1953[2]					
July 7	Concentrate	Mist blower	2.333 gallons	Lead arsenate	6 pounds: 50 gallons
15			1.778		6 50
Aug. 6			2.611		6 50

[1] A tree unit contains 4200 cubic feet, a volume typical of many mature, bearing McIntosh trees in Maine.
[2] Experiment in the Taylor Orchard. All other experiments were in the Frost Orchard.

TABLE 6

Quantities of Insecticides (active ingredients) Applied for Apple Fruit Fly Control

Year	Method of application	Insecticide	Dates of application, and quantity of insecticide (pound per tree unit[1]) applied on specified dates			
1947	Dust		July 9	July 16	July 22	July 31
		Lead arsenate	.480	.400	.305	.252
		DDT	—	—	.102	.084
1948	Dust		July 13	July 20	July 29	
		Lead arsenate	.279	.284	.248	
1949	Dust		July 1	July 14	July 20	July 29
		Lead arsenate	.309	.286	.440	.237
1950	Liquid		June 29	July 7	July 15	Aug. 1
		Lead arsenate	.143	.168	.173	.207
1951	Liquid		July 2	July 10	July 24	July 30
		Lead arsenate	.247	.298	.270	.213
1952	Liquid		June 27	July 11	July 24	
		Lead arsenate	.181	.192	.234	
1953	Liquid		July 7	July 15	Aug. 6	
		Lead arsenate	.275	.237	.332	
1953[2]	Liquid		July 7	July 15	Aug. 6	
		Lead arsenate	.280	.213	.313	

[1] A tree unit contains 4200 cubic feet, a volume typical of many mature, bearing McIntosh trees in Maine.
[2] Experiment in the Taylor Orchard. All other experiments were in the Frost Orchard.

TABLE 7

APPLE FRUIT FLY

Number of Rains and Quantity of Precipitation Between Insecticide Applications, and During 10 Days Following Last Application

Year	Dates of application, number of rains, and quantity of precipitation (inches)				
1947	Dates	July 9	July 16	July 22	July 31
	Number of rains	2	4	4	0
	Precipitation	.76	1.25	1.05	0
1948	Dates	July 13	July 20	July 29	
	Number of rains	2	2	2	
	Precipitation	.35	.48	.39	
1949	Dates	July 1	July 14	July 20	July 29
	Number of rains	1	1	2	2
	Precipitation	.37	.06	.09	.54
1950	Dates	June 29	July 7	July 15	Aug. 1
	Number of rains	6	3	5	2
	Precipitation	.90	.47	.62	.86
1951	Dates	July 2	July 10	July 24	July 30
	Number of rains	2	6	1	5
	Precipitation	1.34	4.20	.47	1.23
1952	Dates	June 27	July 11	July 24	
	Number of rains	3	2	3	
	Precipitation	.03	.24	.50	
1953	Dates	July 7	July 15	Aug. 6	
	Number of rains	3	5	2	
	Precipitation	1.32	2.13	.66	

TABLE 8

Deposit on Apple Leaves from Insecticides Applied for Apple Fruit-Fly Control
McIntosh Apple Trees in the Frost Orchard

Year	Insecticide	Deposit (mg. per 1000 sq. cm.)[1] on specified sampling dates									
1947		July 9	July 12	July 15	July 16	July 18	July 25	July 29	July 31	Aug. 4	Aug. 16
	Lead arsenate[2]	7.43	4.93	3.52	9.55	5.73	5.04	3.45	5.94	4.94	3.92
	DDT	1.35	—	—	—	0.62	1.87	0.95	2.46	1.29	0.93
1950		June 29	July 5	July 7	July 13	July 14	July 20	Aug. 2	Aug. 12	Aug. 18	
	Lead arsenate	9.22	6.77	10.74	8.38	13.75	12.24	11.57	8.61	8.66	
1951		July 3	July 7	July 10	July 20	July 24	July 28	July 30	Aug. 11	Aug. 18	Aug. 23
	Lead arsenate	11.70	8.30	16.16	10.62	15.70	17.32	19.43	16.65	14.26	14.36
1952		June 27	July 10	July 11	July 23	July 24	Aug. 22				
	Lead arsenate	8.24	7.43	13.49	10.36	18.19	10.16				
1953		July 8	July 29	Aug. 6							
	Lead arsenate	13.09	10.30	18.76							

[1] Chemical analyses by Bernie E. Plummer, Jr., Chemist, Maine Experiment Station.
[2] The arsenical deposit from lead arsenate is stated as As_2O_3.

TABLE 9

Comparison of Arsenical Deposits on Apple Leaves from the Upper and the Lower Parts of Trees Sprayed with Lead Arsenate

Year	Upper or lower part of trees	Deposit of arsenic (As_2O_3, mg. per 1000 sq. cm.)[1] on specified sampling dates									
		July 3	July 7	July 10	July 20	July 24	July 28	July 30	Aug. 11	Aug. 18	Aug. 23
1951	Upper	4.68	4.02	10.81	6.08	9.85	7.88	11.13	8.22	5.77	6.39
	Lower	11.70	8.30	16.16	10.62	15.70	17.32	19.43	16.65	14.26	14.36
		June 27	July 10	July 11	July 23	July 24	Aug. 22				
1952	Upper	2.51	4.65	5.43	3.29	6.51	1.89				
	Lower	8.24	7.43	13.49	10.36	18.19	10.16				

[1] Chemical analyses by Bernie E. Plummer, Jr., Chemist, Maine Experiment Station.

TABLE 10

APPLE FRUIT FLY

Insecticide Application Dates in Relation to the Percentage of Flies That Had Emerged

Year	Dust or liquid	Application dates and the percentage of flies that had emerged by the time of each application							
		Date	Emergence per cent	Date	Emergence per cent	Date	Emergence per cent	Date	Emergence per cent
1947	Dust	July 9	0.14	July 16	14.5	July 22	41.8	July 31	93.5
1948	Dust	July 13	0.28	July 20	9.9	July 29	53.9		
1949	Dust	July 1	0.70	July 14	34.6	July 20	67.7	July 29	91.9
1950	Liquid	June 29	0	July 7	1.6	July 15	21.7	Aug. 1	90.0
1951	Liquid	July 2	0.05	July 10	3.9	July 24	61.4	July 30	89.7
1952	Liquid	June 27	0.01	July 11	22.5	July 24	84.5		
1953	Liquid	July 7	0.10	July 15	6.0	Aug. 6	92.4		
1953[1]	Liquid	July 7	0.10	July 15	6.0	Aug. 6	92.4		

[1] Experiment in the Taylor Orchard. All other experiments were in the Frost Orchard.

TABLE 11

APPLE FRUIT FLY

Control Obtained from Insecticide Applications

Year	Dust or liquid	Number of applications	Apples examined		Apples stung per cent		Reduction per cent
			Check plot	Treated plot	Check plot	Treated plot	
1947	Dust	4	400	1200	61.0	9.3	84.8
1948	Dust	3	500	3000	76.8	9.7	87.4
1949	Dust	4	400	1200	43.3	15.4	64.4
1950	Liquid	4	500	2000	26.2	5.7	78.2
1951	Liquid	4	500	2000	4.0	0.6	85.0
1952	Liquid	3	500	2000	71.6	19.3	73.0
1953	Liquid	3	—	2000	—	12.3	—
1953[1]	Liquid	3	—	1000	—	0.3	—

[1] Experiment in Taylor Orchard. All others were in the Frost Orchard.

TABLE 12

APPLE FRUIT FLY

Insecticide Residues[1] on Apples at Picking Time
McIntosh Apples From Frost Orchard

Year	Date of sample	Number of apples	Arsenic[2] ppm	DDT ppm
1947	Sept. 26	10	0.92	—
		10	0.89	—
		10	—	0.61
		10	—	0.46
1951	Sept. 18	5	1.79	—
		5	1.63	—

[1] Chemical analyses by Bernie E. Plummer, Jr., Chemist, Maine Experiment Station.

[2] Arsenic stated as As_2O_3.

TABLE 13

CONTROL OF PLUM CURCULIO

Monmouth, Maine—1948-1952

Year	Kind[1] of application	Insecticide	Applications: Petal fall	Applications: Covers			Apples injured[2]: Untreated checks	Apples injured[2]: Test plots	Reductio
							Per cent		Per cen
1952	Liquid	Lead ars.	June 3(3)[3]	—	—	June 27(27)[3]	20.4	1.8	91.2
1951	Liquid	Lead ars.	May 29(3)	—	June 5(10)	July 2(37)	4.0	0.55	86.3
		DDT	—	May 31(5)	—	—			
1950	Dust	Lead ars.	June 2(2)	—	June 16(16)	June 29(29)			
	Liquid	DDT	—	June 6(6)	—	—	14.0	3.1	77.9
		Lead ars.	May 23(4)	May 26(7)	May 28(9)	June 1(13)			
		DDT	—	—	—	June 1(13)			
1949	Dust	Lead ars.		June 3(15)	June 6(18)	June 13(25)	32.5	2.6	92.0
		DDT		—	June 6(18)	June 13(25)			

[1] Liquid applied as concentrated mist spray equivalent to 3 pounds lead arsenate or DDT 50% wettable powde per 100 gallons of standard spray. Dust contained 15% lead arsenate, 5% DDT applied with water mist Niagara "Cyclone" liquid-duster used for both liquid and dust applications.

[2] In 1950, '51, and '52, 2000 apples from the test plots, and 500 from the untreated check plots were examine each year. In 1949, 1200 apples from the test plots, and 400 from the untreated check plots were examined

[3] Figures in parentheses show the number of days after petal fall when each application was made.

TABLE 14

SPRAY PROGRAM[1]

Frost Orchard 1951

Application No.	Date	Name	Plots	Bentonite sulphur dust[2] (Lbs.)	Bentonite sulphur wettable (Lbs.)	Dry lime sulphur (Lbs.)	Glyodin[3] ("341") (Qts.)	Lead arsenate (Lbs.)	DDT 5% dust[2] (Lbs.)	DDT 50% wettable (Lbs.)
	May 3	E. prepink	1, 2, 3, 4, Ch.	280	—	20	—	—	—	—
	10	Prepink		290	—	20	—	—	—	—
	17	Pink		390	—	20	—	—	—	—
	22	Bloom		490	10	—	—	—	—	—
	29	Petal fall	1 and 3	—	—	—	9	12	—	—
			2 and 4	—	30	—	—	12	—	—
	31	Oystershell	1, 2, 3, 4, Ch.	—	—	—	—	—	245	15
	June 5	Cover	1 and 3	—	—	—	9	12	—	—
			2 and 4	—	30	—	—	12	—	—
	11	Cover	1 and 3	—	—	—	9	—	—	—
			2 and 4	—	30	—	—	—	—	—
	18	Cover	1 and 3	—	—	—	9	—	—	—
			2 and 4	—	30	—	—	—	—	—
	25	Cover	1 and 3	—	—	—	9	—	—	—
			2 and 4	—	50	—	—	—	—	—
	July 2	Cover	1 and 3	—	—	—	9	16	—	—
			2 and 4	—	50	—	—	16	—	—
	10	Cover	1 and 3	—	—	—	9	16	—	—
			2 and 4	—	50	—	—	16	—	—
	16	Cover	1 and 3	—	—	—	9	—	—	—
			2 and 4	—	50	—	—	—	—	—
	24	Cover	1 and 3	—	—	—	9	16	—	—
			2 and 4	—	50	—	—	16	—	—
	30	Cover	1 and 3	—	—	—	9	16	—	—
			2 and 4	—	50	—	—	16	—	—

[1]Applications were made with a liqui-duster.
[2]Material applied as dust; total quantity applied is shown. All other materials were applied in concentrate mist spray; quantity shown is amount used in 60 gallons of water. When both dust and wettable materials were used in the same application, the wettable ingredient was applied in concentrate mist spray along with the dust.
[3]"Crag Fruit Fungicide 341" contains 34 per cent glyodin.

TABLE 15

SPRAY PROGRAM[1]

Frost Orchard 1952

Application No.	Date	Name	Plots	Bentonite sulphur dust[2] (Lbs.)	Bentonite sulphur + Lead arsenate 15% dust[2] (Lbs.)	Bentonite sulphur wettable (Lbs.)	Lime sulphur (liquid) (Gals.)	Dry lime sulphur (Lbs.)	Glyodin[3] ("341") (Qts.)	Lead arsenate (Lbs.)
	May 5	Early prepink	1, 2, 3, 4, Ch.	350	—	—	4	—	—	—
	12	Prepink		372	—	—	—	20	—	—
	19	Early pink		—	350	—	—	20	—	—
	24	Pink		355	—	—	—	20	—	—
	29	Bloom		350	—	40	—	—	—	—
	June 3	Petal fall	1 and 3	—	—	30	—	—	—	12
			2 and 4	—	—	—	—	—	7	12
	16	Cover	1 and 3	—	—	30	—	—	—	—
			2 and 4	—	—	—	—	—	7	—
	27	Cover	1 and 3	—	—	30	—	—	—	12
			2 and 4	—	—	—	—	—	6	12
	July 11	Cover	1 and 3	—	—	30	—	—	—	12
			2 and 4	—	—	—	—	—	5	12
	24	Cover	1 and 3	—	—	20	—	—	—	12
			2 and 4	—	—	—	—	—	4	12

[1]Applications were made with a liqui-duster.
[2]Material applied as dust; total quantity applied is shown. All other materials were applied in concentrate mist spray; quantity shown is amount used in 60 gallons of water. When both dust and wettable materials were used in the same application, the wettable ingredient was applied in concentrate mist spray along with the dust.
[3]"Crag Fruit Fungicide 341" contains 34 per cent glyodin. Hydrated lime, 1 pound in 50 gallons of water, was used with the glyodin.

TABLE 16

SPRAY PROGRAM[1]

Frost Orchard 1953

Application No.	Application Date 1953	Name	Plots	Bentonite sulphur + Lead arsenate 10% dust[2] (Lbs.)	Lime sulphur (liquid) (Gals.)	Sulphur micronized wettable (Lbs.)	Glyodin[3] ("341") (Qts.)	Lead arsenate (Lbs.)
1	May 8	Prepink	1, 2, 3, 4, Ch.	345	4	—	—	—
2	15	Pink		350	4	—	—	—
3	23	Bloom	1 and 3	—	—	16	—	—
			2 and 4	—	—	—	6	—
4	28	Petal fall	1 and 3	—	—	16	—	6
			2 and 4	—	—	—	7	6
5	June 6	Cover	1 and 3	—	—	16	—	6
			2 and 4	—	—	—	6	6
6	12	Cover	1 and 3	—	—	16	—	—
			2 and 4	—	—	—	6	—
7	25	Cover	1 and 3	—	—	16	—	5
			2 and 4	—	—	—	5	5
8	July 8	Cover	1 and 3	—	—	16	—	6
			2 and 4	—	—	—	2	6
9	15	Cover	1 and 3	—	—	16	—	6
			2 and 4	—	—	—	1.5	6
10	Aug. 6	Cover	1 and 3	—	—	16	—	6
			2 and 4	—	—	—	1.5	6

[1] Applications were made with a liqui-duster. The same program was applied in the Taylor Orchard. The quantities of dusts used varied in the two orchards.

[2] Material applied as dust; total quantity applied is shown. All other materials were applied in concentrate mist spray; quantity shown is amount used in 50 gallons of water. When both dust and wettable materials were used in the same application, the wettable ingredient was applied in concentrate mist spray along with the dust.

[3] "Crag Fruit Fungicide 341" contains 34 per cent glyodin. Hydrated lime, 1 pound in 50 gallons of water, was used with the glyodin.

TABLE 17

European Red Mite Populations, Frost Orchard, 1951
Mites and Eggs on Primary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers						
		Check plot	Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
June 13	Mites	1.24	3.16	7.28	5.22	4.18	4.22	4.20
	Eggs	10.58	13.82	21.20	17.51	16.68	18.56	17.62
18-19	Mites	3.20	7.56	13.10	10.33	15.10	11.34	13.22
	Eggs	5.48	8.82	20.18	14.50	15.36	17.96	16.60
25-26	Mites	4.52	9.54	13.16	11.35	10.90	16.36	13.63
	Eggs	1.40	2.94	4.18	3.56	2.08	2.58	2.33
July 2-4	Mites	3.08	4.52	7.24	5.88	6.60	8.36	7.48
	Eggs	10.20	10.50	13.14	11.82	18.62	14.82	16.72
9-11	Mites	7.54	13.12	5.94	9.53	13.54	8.12	10.83
	Eggs	21.04	20.88	26.14	23.51	37.98	30.68	34.33
16-17	Mites	16.52	13.78	14.84	14.31	27.88	21.78	24.83
	Eggs	12.08	9.06	15.42	12.24	10.88	11.44	11.16
23-24	Mites	18.46	7.44	12.98	10.21	18.64	24.16	21.40
	Eggs	23.86	16.28	18.98	17.63	30.06	17.66	23.86
30-31	Mites	15.90	7.96	7.88	7.92	18.14	13.50	15.82
	Eggs	37.74	23.28	28.54	25.91	34.66	36.74	35.70
Aug. 6-7	Mites	21.84	22.76	12.88	17.82	24.04	22.24	23.14
	Eggs	30.12	20.16	23.16	21.66	26.20	30.60	28.40
13-14	Mites	12.28	12.64	9.44	11.04	25.96	21.28	23.62
	Eggs	6.44	12.20	11.72	11.96	12.04	11.16	11.60
20-21	Mites	1.00	7.08	4.12	5.60	16.64	14.24	15.44
	Eggs	2.40	8.56	4.28	6.42	7.48	6.88	7.18
27-28	Mites	.24	3.24	1.80	2.52	8.96	9.56	9.26
	Eggs	.80	4.80	5.24	5.02	5.52	5.56	5.54
Sept. 2-3	Mites	.20	2.52	1.16	1.84	5.96	5.12	5.54
	Eggs	.64	3.28	2.56	2.92	3.64	3.28	3.46

[1] Counts made on 100 leaves from each plot on each date; on ½ of each leaf, June 13 to July 31, inclusive, and on ¼ of each leaf on later dates. All of the data shown in tables 17 to 25, inclusive, are from McIntosh apple trees.

TABLE 18

European Red Mite Populations, Frost Orchard, 1951
Mites and Eggs on Secondary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers						
		Check plot	Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
June 13	Mites	.22	1.94	3.90	2.92	2.22	3.82	3.02
	Eggs	1.54	7.58	15.50	11.54	10.38	17.92	14.15
18-19	Mites	1.04	6.48	14.04	10.26	14.10	8.60	11.35
	Eggs	1.82	8.24	19.38	13.81	15.58	14.10	14.84
25-26	Mites	4.70	8.72	18.46	13.59	15.72	16.60	16.16
	Eggs	1.20	3.28	5.82	4.55	8.46	2.56	5.51
July 2-4	Mites	3.62	6.36	13.74	10.05	11.32	14.06	12.69
	Eggs	10.82	16.72	29.00	22.86	40.66	31.92	36.29
9-11	Mites	9.96	12.70	14.28	13.49	24.16	25.66	24.91
	Eggs	22.96	29.12	54.84	41.98	53.76	64.80	59.28
16-17	Mites	25.72	24.24	40.18	32.21	62.48	70.58	66.52
	Eggs	16.00	14.90	29.48	22.19	19.46	24.62	22.04
23-24	Mites	25.16	18.06	31.82	24.94	43.98	56.96	50.47
	Eggs	37.38	29.80	46.30	38.05	58.24	38.16	48.20
30-31	Mites	31.82	16.52	19.96	18.24	40.82	39.10	39.96
	Eggs	65.54	49.14	61.30	55.22	79.68	82.82	81.10
Aug. 6-7	Mites	49.08	29.32	32.68	31.00	64.24	64.80	64.52
	Eggs	52.84	42.76	54.72	48.74	64.80	70.24	67.52
13-14	Mites	33.84	27.00	26.28	26.64	70.92	65.80	68.36
	Eggs	11.40	26.12	31.28	28.70	29.80	31.28	30.54
20-21	Mites	4.00	17.68	13.84	15.76	52.44	51.92	52.18
	Eggs	2.92	17.04	15.28	16.16	24.52	21.80	23.16
27-28	Mites	.88	6.96	3.60	5.28	23.80	26.20	25.00
	Eggs	1.08	10.68	12.92	11.80	18.24	13.00	15.62
Sept. 2-3	Mites	.52	6.20	1.92	4.06	14.36	13.16	13.76
	Eggs	1.28	7.24	5.72	6.48	8.60	8.56	8.58

[1] Counts made on 100 leaves from each plot on each date. Counts made on ½ of each leaf, June 13 to July 31, inclusive, and on ¼ of each leaf on later dates.

TABLE 19

European Red Mite Populations, Frost Orchard, 1952
Mites and Eggs on Primary Leaves[1]

Date of count	Stage	Check plot	Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
		Mites and eggs per leaf—average numbers						
June 13-14	Mites	.06	.19	.24	.22	.09	.20	.15
	Eggs	1.94	4.71	5.41	5.06	3.28	4.53	3.91
16-18	Mites	.42	1.31	1.26	1.29	1.15	.86	1.01
	Eggs	1.92	4.72	3.67	4.20	3.87	2.54	3.21
23-25	Mites	1.27	2.38	3.27	2.83	2.35	1.63	1.99
	Eggs	1.31	1.39	1.80	1.60	1.88	.97	1.43
July 1-2	Mites	.60	1.31	1.85	1.58	1.06	.94	1.00
	Eggs	1.21	1.26	2.44	1.85	1.62	1.90	1.76
7-9	Mites	.46	1.26	1.69	1.48	.74	1.52	1.13
	Eggs	3.48	4.47	6.01	5.24	5.15	6.35	5.75
14-17	Mites	1.55	5.78	6.20	5.99	3.33	3.63	3.47
	Eggs	1.61	3.77	7.47	5.62	4.49	2.85	3.67
21-24	Mites	3.70	3.50	6.32	4.91	2.84	3.38	3.11
	Eggs	9.98	12.78	27.82	20.30	11.76	13.46	12.61
Aug. 4-7	Mites	11.32	10.58	21.50	16.04	8.50	13.50	11.00
	Eggs	14.22	12.38	22.44	17.41	16.34	16.04	16.19
11-14	Mites	10.28	11.72	24.36	18.04	12.60	13.00	12.80
	Eggs	26.04	20.74	39.70	30.22	22.90	19.70	21.30
18-21	Mites	14.80	16.10	25.94	21.02	13.40	17.14	15.27
	Eggs	22.14	26.34	37.52	31.93	27.78	21.62	24.70
25-28	Mites	14.32	17.80	32.02	24.91	17.22	14.88	16.05
	Eggs	13.52	17.38	22.56	19.97	16.66	16.16	16.41

[1] Counts made on 100 leaves from each plot on each date; on the whole of each leaf, June 13 to July 17, inclusive; and ½ of each leaf on later dates.

TABLE 20

European Red Mite Populations, Frost Orchard, 1952
Mites and Eggs on Secondary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers						
		Check plot	Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
June 13-14	Mites	0	.04	.26	.15	.01	.06	.04
	Eggs	.40	1.23	2.33	1.78	.73	1.02	.88
16-18	Mites	.13	.50	.75	.63	.19	.19	.19
	Eggs	.45	2.22	2.72	2.47	.70	.80	.75
23-25	Mites	.60	.78	2.42	1.60	.60	.73	.67
	Eggs	.21	.33	.91	.62	.27	.38	.33
July 1-2	Mites	.69	.71	1.40	1.05	.52	.71	.62
	Eggs	.90	1.30	2.47	1.89	.73	1.52	1.13
7-9	Mites	.82	.56	3.34	1.95	.78	1.19	.99
	Eggs	2.53	3.16	6.81	4.99	2.77	4.27	3.52
14-17	Mites	2.24	3.23	7.36	5.30	2.45	3.35	2.90
	Eggs	1.88	1.37	7.17	4.27	3.38	4.06	3.72
21-24	Mites	2.96	1.44	6.70	4.07	3.28	4.22	3.75
	Eggs	7.68	8.98	27.60	18.29	14.02	15.04	14.52
Aug. 4-7	Mites	11.14	10.72	28.50	19.61	7.56	9.92	8.74
	Eggs	14.14	11.16	28.82	19.99	13.58	15.26	14.42
11-14	Mites	10.62	13.28	31.32	22.30	9.12	10.78	9.95
	Eggs	21.04	22.86	43.48	33.17	19.10	22.52	20.81
18-21	Mites	15.92	14.02	34.84	24.43	12.34	13.68	13.01
	Eggs	18.52	20.72	44.24	32.48	23.40	20.86	22.13
25-28	Mites	17.02	20.62	45.28	32.95	14.30	21.94	18.12
	Eggs	19.32	16.84	30.00	23.42	15.06	21.54	18.30

[1] Counts made on 100 leaves from each plot on each date; on the whole leaf, June 13 to July 17, inclusive; on ½ of each leaf on later dates.

TABLE 21

European Red Mite Populations, Frost Orchard, 1953
Mites and Eggs on Primary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers					
		Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
June 29-30	Mites	8.58	16.38	12.48	7.70	7.78	7.74
	Eggs	20.96	43.50	32.23	25.20	33.42	29.31
July 6-7	Mites	11.48	25.76	18.62	10.66	15.90	13.28
	Eggs	40.46	64.54	52.50	38.84	40.00	39.42
13-16	Mites	34.88	56.12	45.50	24.48	21.14	22.81
	Eggs	25.02	31.84	28.43	25.60	20.56	23.08
20-23	Mites	28.36	45.80	37.08	17.04	12.20	14.62
	Eggs	19.74	21.32	20.53	28.20	28.12	28.16
28-30	Mites	18.64	11.90	15.26	12.20	8.30	10.25
	Eggs	36.62	11.34	23.98	25.80	20.60	23.20
Aug. 3-4	Mites	22.48	6.44	14.46	7.06	8.12	7.59
	Eggs	36.22	7.54	21.88	8.06	11.18	9.62
11-12	Mites	19.22	1.80	10.51	1.46	3.62	2.54
	Eggs	13.76	4.18	8.97	3.70	5.48	4.59
17	Mites	12.04	1.14	6.59	.44	.86	.65
	Eggs	7.48	3.86	5.67	1.60	2.58	2.09
23	Mites	7.52	.46	3.99	.18	.72	.45
	Eggs	7.28	2.50	4.89	1.20	1.36	1.28

[1] Counts made on ½ of each of 100 leaves on each date.

TABLE 22

European Red Mite Populations, Frost Orchard, 1953
Mites and Eggs on Secondary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers					
		Plot 1	Plot 3	Plots 1 + 3	Plot 2	Plot 4	Plots 2 + 4
June 29-30	Mites	9.04	26.76	17.90	6.60	9.04	7.82
	Eggs	31.34	81.32	56.33	33.64	55.86	44.75
July 6-7	Mites	17.80	69.18	43.49	14.34	23.18	18.76
	Eggs	65.88	139.78	102.83	53.56	51.40	52.48
13-16	Mites	52.06	134.80	93.43	36.32	28.76	32.54
	Eggs	31.18	68.86	50.02	37.18	28.82	33.00
20-23	Mites	45.16	103.22	74.19	29.98	19.52	24.75
	Eggs	39.10	49.42	44.26	56.16	54.02	55.09
28-30	Mites	43.04	34.70	38.87	28.44	16.80	22.62
	Eggs	88.08	38.54	63.31	61.86	40.12	50.99
Aug. 3-4	Mites	50.86	18.66	34.76	14.78	17.92	16.35
	Eggs	88.24	24.18	56.21	15.72	26.88	21.30
11-12	Mites	52.94	5.18	29.06	2.50	7.48	4.99
	Eggs	36.42	11.78	24.12	8.84	14.40	11.62
17	Mites	34.92	2.78	18.85	.58	1.90	1.24
	Eggs	20.20	10.10	15.15	3.34	4.90	4.12
23	Mites	15.34	1.42	8.38	.16	.88	.52
	Eggs	14.34	6.78	10.56	2.56	2.72	2.64

[1] Counts made on ½ of each of 100 leaves on each date.

TABLE 23

European Red Mite Populations, Taylor Orchard, 1953
Mites and Eggs on Primary and Secondary Leaves[1]

Date of count	Stage	Mites and eggs per leaf—average numbers			
		Primary leaves		Secondary leaves	
		Plot 1	Plot 2	Plot 1	Plot 2
July 3	Mites	.01	.13	.01	.07
	Eggs	.01	1.07	0	.64
10	Mites	.01	.23	.02	.17
	Eggs	.19	.99	0	.30
15	Mites	.01	.43	.16	.30
	Eggs	.12	.29	.10	.11
24	Mites	.15	.54	.09	.45
	Eggs	.81	2.82	.32	1.66
30	Mites	.52	1.94	.60	.91
	Eggs	1.46	4.67	1.60	2.42
Aug. 7	Mites	1.04	3.80	1.50	2.81
	Eggs	1.47	6.82	2.37	5.87
15	Mites	1.63	3.97	1.50	4.65
	Eggs	4.29	12.25	3.09	14.04
19-20	Mites	1.30	5.06	1.46	5.97
	Eggs	4.57	18.03	4.81	17.13

[1] Counts of mites and eggs on 100 whole leaves on each date.

TABLE 24

Weights of McIntosh Apples from Experimental Plots

Orchard	Year	Post-bloom fungicide	Number of apples in sample	Average weight, 100 apples: Pounds		Average weight, 100 apples: Difference per cent
Frost	1951	1. Glyodin	1000	29.73		
		2. Sulphur	1000	28.86	(1-2)	2.93
	1952	1. Glyodin	1000	22.49		
		2. Sulphur	1000	22.19	(1-2)	5.91
	1953	1. Glyodin	1000	25.79		
		2. Sulphur	1000	25.08	(1-2)	2.75
Taylor	1953	1. Glyodin	500	25.07		
		2. Sulphur	500	26.06	(2-1)	3.80

TABLE 25

Chlorophyll Content of McIntosh Apple Leaves from Experimental Plots

Orchard	Year	Post-bloom fungicide	Chlorophyll (1000 sq. cm. leaf area): Mg.		Chlorophyll (1000 sq. cm. leaf area): Difference Per cent
Frost	1951	1. Glyodin	18.86[1]		
		2. Sulphur	13.06[1]	(1-2)	30.75
	1952	1. Glyodin	28.16[2]		
		2. Sulphur	26.25[2]	(1-2)	6.78
	1953	1. Glyodin	37.05[2]		
		2. Sulphur	23.70[2]	(1-2)	36.03
Taylor	1953	1. Glyodin	35.88[3]		
		2. Sulphur	32.12[3]	(2-1)	10.48

[1] Average of 6 samples from each treatment. Each sample included 50 leaf sections (Lathrop et al., 1944), with a total area of 599.47 sq. cm.
[2] Average of 4 samples from each treatment.
[3] Average of 2 samples from each treatment.